A Classification of Forest Habitat Types of the Lincoln National Forest, New Mexico

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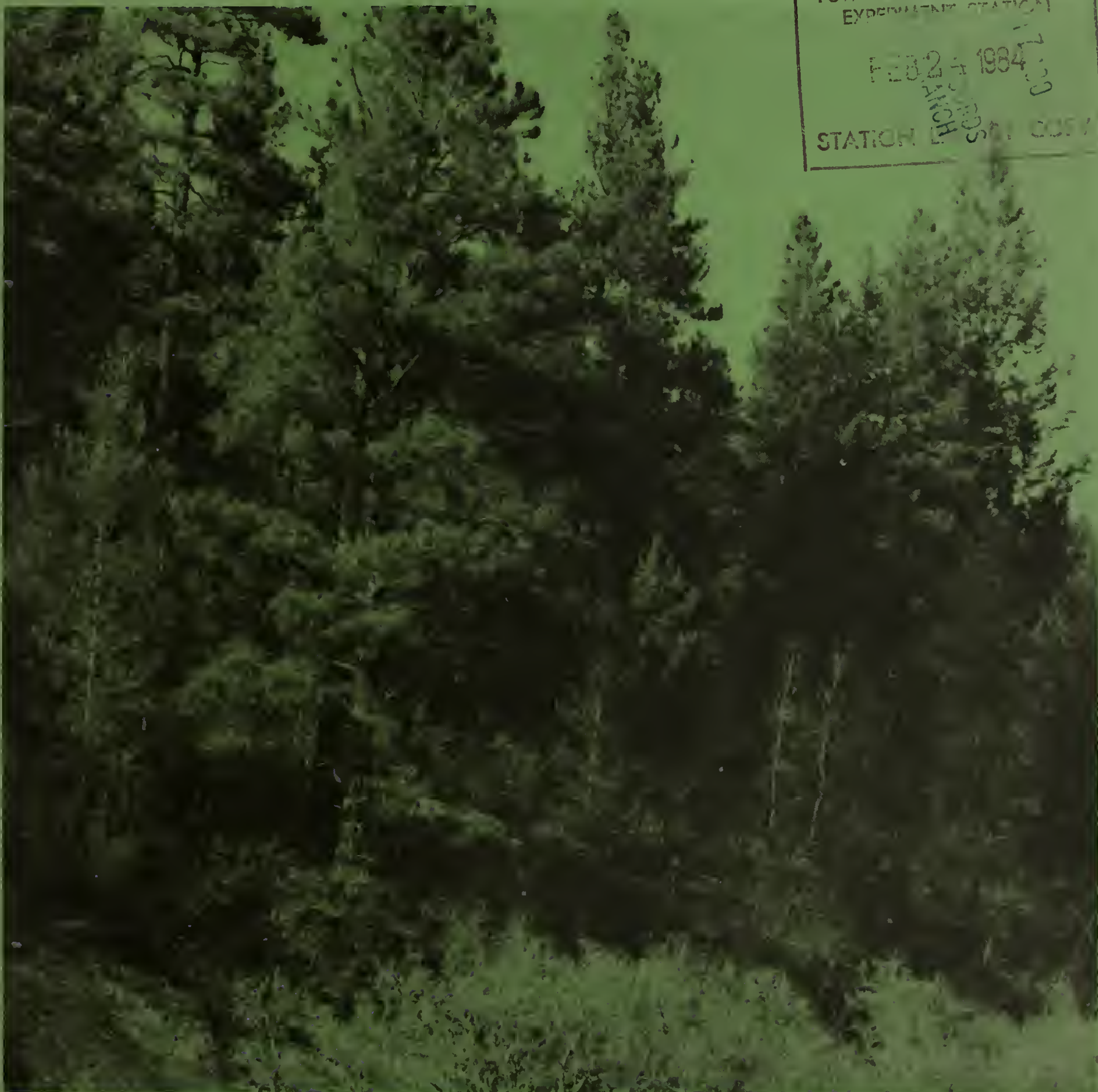

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Abstract

Vegetational data were collected from the Lincoln National Forest, New Mexico, to develop a forest habitat classification based on potential natural vegetation. There are 13 habitat types and, in addition, several phases identified on the Lincoln National Forest; 8 were previously classified by Moir and Ludwig (1979), and 5 by this study. The 13 habitat types represent 6 climax forest series: *Abies lasiocarpa*, *Picea engelmannii*, *Picea pungens*, *Abies concolor*, *Pseudotsuga menziesii*, and *Pinus ponderosa*. Each habitat type is described according to vegetational composition, topographical occurrence, soils information (when known), ecotones, adjacent habitat types, and general features.

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A Classification of Forest Habitat Types of the Lincoln National Forest, New Mexico[1]

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Contents

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INTRODUCTION

This vegetational classification of forest habitat types for the Lincoln National Forest is applicable to all climax forest series from the low-elevation ponderosa pine to the high spruce-fir. It is based on the concept of potential natural vegetation. The habitat types described here are believed to represent forests in a mature, nondisturbed condition or climax state.

Site classification is important from a management standpoint because it helps to provide a crucial understanding of the ecological aspects of Southwestern forests. It also provides an organizational step in predicting ecological responses to forest treatments. Forest classification based on potential natural vegetation is relatively new to the Southwest. Previous classification work on the Lincoln National Forest by Moir and Ludwig (1979) identified ten mixed conifer and spruce-fir forest types. Dye and Moir (1977) described the compositional elements of a spruce-fir forest near Sierra Blanca Peak on the Lincoln National Forest. Their study showed possible similarities between the southern and northern spruce-fir forests in the Rocky Mountains. Hanks and Dick-Peddie (1974) studied successional trends in the White Mountains, a prominent range of mountains on the Lincoln, and identified various stages of succession after disturbance. Hanks (1966) presents a somewhat more basic synthesis of a similar nature.

In addition to developing a forest habitat type classification for the Lincoln National Forest, this study also involved three other objectives: (1) to test previous classification work by Moir and Ludwig (1979), (2) to clarify successional trends, and (3) to propose management applications. Although some management implications may be inferred, or explicitly stated, from the habitat type descriptions, full development of this subject must await future studies and summaries of existing information.

Although the terminology used in this paper is commonly accepted and follows that of Daubenmire (1968), who presents a comprehensive discussion of terminology, the following terms are defined for emphasis. A *plant association* is the dominant plant community representing *potential natural vegetation*, which is the climax vegetation existing on a site after natural succession has occurred in the absence of disturbance. All the areas that are capable of supporting the same plant association are termed a *habitat type* (HT), while a *phase* (P) is a subdivision of the habitat type based on the presence or abundance of an indicator species.

STUDY AREA

The Lincoln National Forest, located in south-central New Mexico, contains some of the southernmost extensive stands of forest in the western United States. The Forest lies east of the Rio Grande River, west of the Texas High Plains, south of the contiguous Rocky Mountains, and north of the Chihuahuan Desert (fig. 1). It is distinct from the Colorado Plateau, and lies in an area that is heavily faulted. As with many Southwestern mountains, those on the Lincoln National Forest are surrounded by desert or grassland, and can be characterized as biogeographical islands. This isolation has special importance in comparing vegetation characteristics between forests of the Southwest (Shreve 1922), and apparently has led to speciation and endemic ecological types in the southwestern United States.

Geography.—The Lincoln National Forest is divided into fragmented mountain ranges, resulting in a mosaic of isolated forests separated by treeless zones. Furthermore, differences between these fragmented mountains and areas outside the Lincoln National Forest appear to be greater than differences within. Thus, a regional

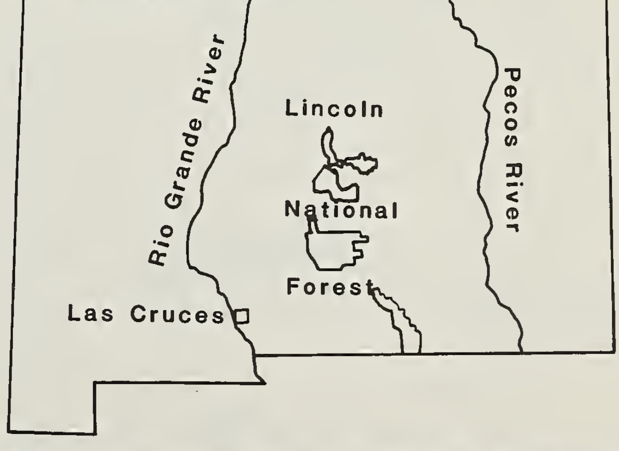

Figure 1.—Location of the Lincoln National Forest in the State of New Mexico.

identity is established for the Forest as far as vegetational habitats are concerned. Four distinct areas are recognized (fig. 2). The Sacramento Mountains are the southern extent of this study, while to the north lie the White Mountains, which include Sierra Blanca Peak. North and east of the White Mountains are a series of smaller mountains—the Carrizo Peak area, including the Jicarrillo and Patos Mountains, and the Capitan Peak area. The Guadalupe Mountains to the south were not included because they did not contain sufficient forested area to meet the objectives of the study.

Geology.—The mountains of the Lincoln National Forest are geologically diverse, with steep elevational relief resulting from numerous uplifts and extrusive actions. The Sacramento Mountains arose primarily from a massive uplift, as evidenced by a steep escarpment on the western flank. The predominant parent material is San Andres Limestone, but in some areas, the underlying Yeso Siltstone is a prominent feature (Weber 1964, Hunt 1977). In addition, the White Mountains, Carrizo Peak area, and the Capitan Mountains are characterized by extrusive volcanic activity and more diverse parent materials. The Sierra Blanca and Nogal Peak areas are dominated by andesitic parent material, and dikes and volcanic plugs often can be found. The Capitan Peak system—a large, linear, east to west range—also exhibits parent material similar to that of the White Mountains. However, the rock has a much redder hue and has been referred to as alaskite.[4] It appears that the Carrizo Peak area is geologically similar.

[4]Personal communication with Cliff Landers, Soil Scientist, USDA Forest Service, Lincoln National Forest, 1979.

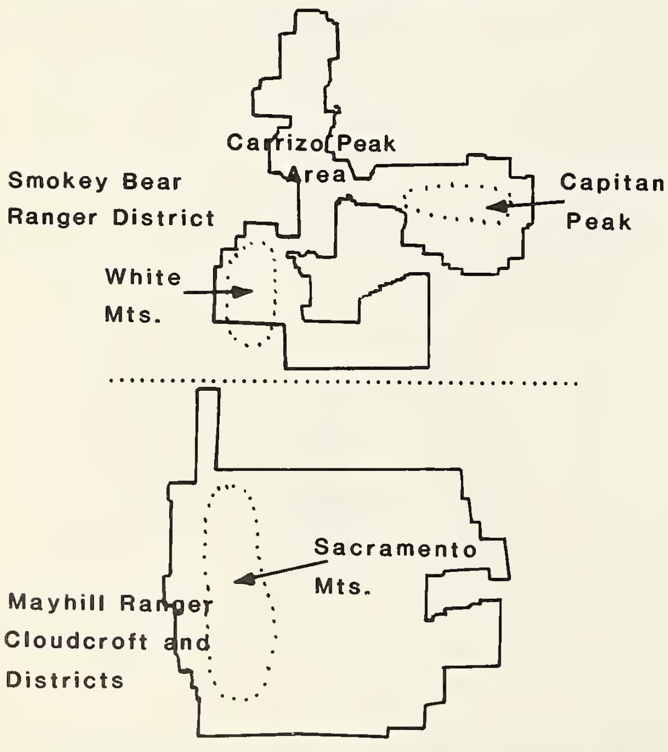

Figure 2.—Geographical divisions of the Lincoln National Forest.

Topography.—Extrusions and uplifts created the typical topographical features of the Lincoln National Forest and probably were largely responsible for the resultant vegetational patterns. The uplifts resulted in steep westerly faces in the Sacramento and White Mountains. In the Sacramento Mountains, the east side exhibits a more gentle overall slope, while the east side of the White Mountains is quite steep as a result of volcanic extrusions.

The steep west and gentle east slope configurations result in narrow vegetational bands on west slopes and wider bands on east slopes. Vegetation on steep slopes exhibits a sharp transition between the xeric pinyon-juniper woodlands and the more mesic mixed conifer stands. The intervening ponderosa pine forest in this area is nearly absent, or at best forms an ecotone. Although other environmental factors undoubtedly exert an influence, the sharp delineation of vegetation probably results primarily from the behavior of northeasterly-easterly summer storms arising in the Tularosa Basin to the west; as these storms move into the mountains, steep elevational gradients create a dramatic increase in precipitation.

The northern half of the Forest has had more volcanic activity, hence the easterly slopes may be as steep as the west slopes. However, on the west slope of both the White Mountains and Carrizo Peak this sharp vegetational zonation appears once again. The Capitan Mountains exhibit great relief on both the north and south slopes, with long alluvial fan systems at lower elevations. The east slope of Capitan Peak is fairly unique, being quite steep and highly dissected.

The presence of water on the Lincoln National Forest is quite variable. Many perennial streams flow in the Sacramento Mountains, creating wet meadows in valleys, whereas agricultural activities in other valleys have led to draining of meadows. The White Mountains to the north also are bisected by several perennial streams, which are utilized for recreation. In contrast, no perennial streams are present either on Carrizo Peak or Capitan Peak, but many springs and ephemeral streams provide habitats for riparian vegetation.

One of the interesting geological features on the Lincoln National Forest is the presence of rock glaciers in the Capitan Peak area. From the ground, the rock slopes appear to be ordinary scree, but viewed from the air, the rock can be seen to have slowly crept down the mountain side. These rock glaciers, while exhibiting sparse vegetational cover, influence water relations on the slope below.

Climate.—Climate throughout the geographical regions of the Southwest exhibits varying patterns, and is undoubtedly a major factor affecting the occurrence of plant associations. Moving easterly through the Southwest, summer precipitation—beginning in July and ending in September—becomes a more prominent part of the annual pattern. Approximately 60% of the annual precipitation falls during this period, but in some areas of the Lincoln National Forest, up to 70% of the rainfall comes during summer months. Spring (from mid-April through June) and fall (October and November) are dry

periods. Annual precipitation for forested areas is between 20 and 30 inches (510 and 760 mm) (fig. 3).[5]

Between 12 and 18 inches (300 and 460 mm) of summer precipitation falls over forested areas, usually as a result of convective storms that develop near the mountains. The major source of moisture for these storms is an influx of moist air from the Gulf of Mexico.[5] While these storms are an important source of moisture during the growing season, especially for herbaceous plants, it is not clear what effect summer moisture has on tree species. Some studies indicate that winter precipitation is the dominant factor for growth and establishment of trees (Fritts 1974).

Precipitation during the winter wet period is mostly snow, which may arise from continental and maritime polar air masses.[5] These result in frontal systems from the northwest and west. Precipitation during this period is 8 to 12 inches (200 to 300 mm), which saturates soils during the spring thaw.

Historical events.—Interpretation of past events, natural or human caused, is critical to understanding the current vegetational composition on the Lincoln National Forest. Fire was, perhaps, the most important historical factor. Scars indicate that fire once was an active part of the environment, occurring on the average every 7 or 8 years in Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum*)[6] forests (Weaver 1951). Biswell (1973) estimated a greater frequency, once every 2 or 3 years. The short time span between fires resulted in low-intensity burning conditions of a noncatastrophic nature because of low fuel accumulations. As a consequence, such fire behavior exerted an adaptive pressure on plants comprising the ecosystem.

[5]USDA, Forest Service, Lincoln National Forest, unpublished hydrological report, 1979.

[6]Nomenclature and authority for plant species identified in this study follow that of Lehr (1978) unless otherwise specified.

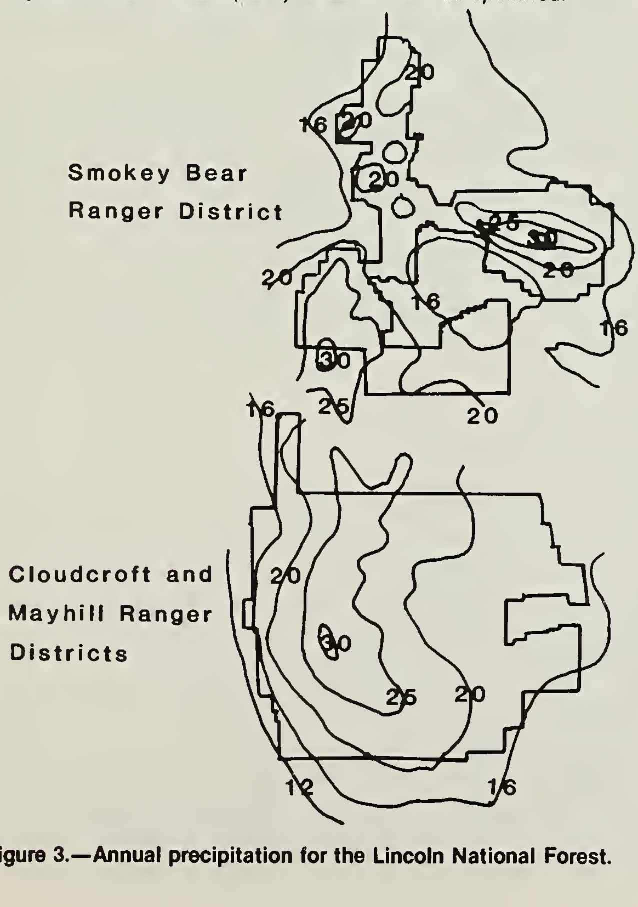

Figure 3.—Annual precipitation for the Lincoln National Forest.

Ponderosa pine is considered a fire-adapted plant. This adaptation appears to have had a profound effect on Southwestern forests which, if left undisturbed, probably would have reached a climax stage composed of less fire-resistant mixed conifer species. Pine overstories essentially were not damaged by the consumption of light fuels and grassy vegetation. Because of greater resistance of pine reproduction to fire, the species could maintain itself and form relatively pure stands. As a consequence, ponderosa pine stands were maintained in a seral state in what otherwise would be mixed conifer forests.

A similar situation also may have existed in the pinyon-juniper transition zone at lower elevations. Fire excluded the less resistant junipers (*Juniperus* spp.) and pinyon (*Pinus edulis*), maintaining again pure stands of ponderosa pine. Essentially, the adaptability of ponderosa pine enabled it to exist in relatively pure stands over a much wider elevational range than if fire had been excluded.

Fire exclusion following settlement and active forest management resulted in invasion by species that are less fire resistant, so that the forest is now in an advanced successional stage in many areas. These forests consist of a mature ponderosa pine overstory, with younger age classes composed of mixed conifer species, such as Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), southwestern white pine (*Pinus strobiformis*), and white fir (*Abies concolor*). Similarly, juniper (primarily *Juniperus deppeana*) and pinyon increased at lower elevations, suggesting that ponderosa pine is seral in such stands. Thus, the zone occupied by pure ponderosa pine stands has been narrowed to those areas where the climate supports climax ponderosa pine forests. This has led to an expression of the climatic climax boundaries of all species independent of the effects of fire. Further discussions of the effects of fire on Southwestern forests can be found in Weaver (1951), Cooper (1960), and Biswell (1973).

The exclusion of high-frequency, low-intensity fires has altered fire behavior on the Lincoln National Forest. High levels of fuel have accumulated, and seedlings of all timber species have increased in number, resulting in very dense fuel ladders. These changes have increased the susceptibility of forests to catastrophic fires and subsequent devastation of the ecosystem. In contrast, some plants are adapted to catastrophic fires; Gambel oak (*Quercus gambelii*) and wavyleaf oak (*Quercus undulata*) are the most notable on the Lincoln National Forest. Old burned areas are now largely fields of oak brush, which do not regenerate easily to conifer species.

Concurrent with increasing suppression of fire, an extensive railroad logging system was established, reaching into nearly every drainage and operating into the mid-1900's. Early logging practices essentially high-

graded the timber, as illustrated by the existence of large stumps next to mature trees deemed not marketable during early harvest.[7] In many locations, a lack of harvesting technology left old-growth stands untouched in inaccessible areas. These pockets often are examples of potential natural vegetation. In some instances, the effects of logging operations hastened establishment of Douglas-fir and southwestern white pine on sites previously dominated by ponderosa pine.

The Lincoln National Forest, in common with all forests in the Southwest, has an extensive grazing history. Following Spanish settlement, sheep were the first domestic animals to use the range, but cattle followed shortly, creating additional grazing pressure. During World War II, goats grazed extensively on the Lincoln National Forest. Although the heaviest use was in and below pinyon-juniper woodlands, animals also utilized forested areas, especially canyon bottoms and other areas near water. Today, even with regulated grazing, species abundance and composition may be altered in plant communities.

Of the more recent activities, recreation has heavily impacted the Lincoln National Forest. Increased use in the past 20 years indirectly affected plant communities through a shift in management goals, including creation of the White Mountain Wilderness and other recreation areas. The direct effect of recreation was modification of some riparian sites or cool drainages, primarily because these preferred use areas are easily adapted to camping and picnicking.

METHODS

FIELD SAMPLING

Procedures for sampling stands followed that of Daubenmire and Daubenmire (1968) as modified by Pfister and Arno (1980) and Moir and Ludwig (1983). First, to increase efficiency of plot selection, individuals with knowledge of the area were contacted, historical data were reviewed, and aerial photographs were used. After general areas were selected, actual plot establishment in the field was made subjectively using the following criteria: (1) presence of a mature tree canopy of sufficient age to allow the undergrowth to stabilize; (2) presence of an undergrowth that had recovered from any past disturbance, as determined by the absence of various indicators such as plants or physical signs; and (3) determination that a stand did not represent an ecotone, in that the undergrowth species composition was not a transition between two distinct areas.

Data were collected under three different procedures—reconnaissance, analytical, and validation. The reconnaissance is a relatively rapid procedure, allowing a large number of plots to be measured in a shorter time compared to the analytical procedure, which requires more detailed and time-consuming measurements. As the term implies, the validation procedure utilized plots primarily to document the presence of known habitat types, which, therefore, were purposely undersampled. Data collected from these plots were similar to, but less detailed than, those of the other two procedures.

[7]*Personal communication with Bill Stanborough, USDA Forest Service, Lincoln National Forest, Timber Staff, 1979.*

Reconnaissance plots were circular (35.8 feet or 10.9 m radius), covering 4,037 square feet (375 m^2). Plant canopy coverage of each undergrowth species was visually estimated to the nearest percent. Trees were recorded in size categories: (1) seedlings—up to 4.5 feet (1.37 m) high, (2) small saplings—4.5 feet (1.37 m) tall to 2 inches (5.1 cm) diameter at breast height (d.b.h.), (3) large saplings/poles—2 to 10 inches (5.1 to 25.4 cm) d.b.h., and (4) mature trees—greater than 10 inches (25.4 cm) d.b.h. In addition, a prism tally was taken to determine basal area.

One analytical plot, 49.2×82.0 feet (15×25 m), was established for about every ten reconnaissance plots, both types of plots providing essentially the same information. Two transect lines, 16.4 feet (5 m) apart, were located parallel to the long axis; 25 rectangular quadrants (7.9×19.7 inches or 20×50 cm) were spaced at 3.3-foot (1-m) intervals along each transect. Plant cover estimates were recorded in percentage coverage classes according to Hanks, et al. (1983). The primary function of analytical plots was to provide calibration between visual estimates of reconnaissance and validation plots and the more precise measurements obtained from quadrats in the analytical method. Also, calibration served to narrow differences in estimates of cover values between investigators in the same or different areas so that data would be comparable. To facilitate calibration, a visually estimated reconnaissance plot was always measured first on the site of an analytical plot. Results of the two methods were compared in the field before leaving the site, and any discrepancies were adjusted by further examination of the plot.

Site data recorded for all plots included aspect, slope, elevation, location, landform, and position (ridge, upper slope, midslope, lower slope, bench, and streamside). The soil surface was described according to the percent (totaling 100) of exposed rocks and mineral soil, litter, moss and lichens, and vascular plant basal area. In addition, such general observations as evidence of fire, logging and grazing influence, mistletoe incidence, tree canopy cover, and general stand conditions were recorded.

DATA ANALYSIS

Development of the classification involved primarily ecological judgment, but more formal computer analyses also were applied for additional refinement. Initially, plots were subjectively grouped into climax forest series according to the dominant overstory species and reproduction. Six series were recognized on the Lincoln National Forest: *Abies lasiocarpa*, *Picea engelmannii*, *Picea pungens*, *Abies concolor*, *Pseudotsuga menziesii*, and *Pinus ponderosa*.

Within a series, individual plots were grouped according to similarities in species composition. Successive refinement utilized relevé tables—data matrices, with coverage values of species in plots (Becking 1957).

Constancy was found to be an important element for determining the reliability of a species as being representative of a given kind of stand. In addition to relevé tables, an analysis of the total list of species and reference to historical data and abiotic features provided further information needed to clarify groupings. Subsequent data analysis utilized ordination—principal component analysis—to improve objectivity, gain additional insight on the interaction of species, substantiate earlier judgments, or reveal types not previously defined (Moir and Ludwig 1983). The process of iterative group refinement—utilizing subjective and analytical computer procedures—was continued until stands were separated into representative units with relatively consistent site characteristics and similar tree, shrub, forb, and graminoid components. When appropriate, these units, or habitat types, were further categorized by phases—a classification level that retains overstory and undergrowth characteristics of habitat types, but differs uniformly and predictably in minor vegetational and site components.

RESULTS AND DISCUSSION

All known habitat types and phases on the Lincoln National Forest, including those developed by this study and by Moir and Ludwig (1979), are listed in table 1, and a key to their identity is shown in appendix A. Habitat types previously described by Moir and Ludwig that were verified but not sampled during this study, are presented essentially as written by these authors.

Nomenclature for habitat types was derived by incorporating the dominant species into the given name. Where habitat types were similar to those already identified outside the study area, the previously assigned name was accepted to retain compatibility between classifications. Subsequent to publication of the work by Moir and Ludwig (1979), nomenclature of the *Abies concolor* series has been revised. More intensive sampling suggested that *Pseudotsuga menziesii* does not always attain the co-climax position it previously was believed to have reached in stands of the *Abies concolor* forest series. As a consequence, *Pseudotsuga menziesii* has been deleted from the name of several *Abies concolor* habitat types. Habitat types that were identified in Moir and Ludwig (1979) as *Abies concolor-Pseudotsuga menziesii/*... now appear as *Abies concolor/*... in this publication. Habitat types represented by only a few plots were determined by comparing such plots with those located on the Gila and Cibola National Forests (Fitzhugh et al.[8]).

Each habitat type description begins with a discussion of diagnostic vegetation characterizing that type. Overstory tree species are described in relation to their climax and successional roles within the habitat type, and plant species most consistently present or absent in the habitat type are labeled diagnostic. Other plants that are not as important as diagnostic species, but that offer clues to field identification of the habitat type, also are discussed. Coverage values reported for a particular species in a habitat type are based on plot averages.

A generalized topographical description is given for each habitat type. However, because environmental factors may be interactive and compensating, a number of topographical locations supporting the same habitat type can exist. There are situations, in contrast, where a habitat type is restricted to a particular topographical situation; for example, the *Abies concolor/Acer grandidentatum* habitat type. Also included in the habitat type description is a discussion of adjacent habitats and ecotones. A discussion section concludes the description of the habitat type, providing additional information gathered during the course of the study.

[8]*E. Lee Fitzhugh, William H. Moir, John A. Ludwig, and Frank Ronco, Jr. Forest habitat types of the Apache, Gila, and part of the Cibola National Forests. Manuscript in preparation.*

SPRUCE-FIR HABITAT TYPES

Abies lasiocarpa Series

Abies lasiocarpa/Senecio sanguisorboides habitat type (ABLA/SESA; subalpine fir/burnet groundsel) (from Moir and Ludwig 1979)

Vegetation.—The overstory is generally dominated by *Abies lasiocarpa*, but sometimes *Picea engelmannii* is co-dominant. *A. lasiocarpa* has moderate to heavy stocking in young and advanced regeneration classes, usually exceeding that of *P. engelmannii*. *Abies concolor* is absent regardless of size class, and *Pseudotsuga menziesii* at low elevations can be a seral component in the stand.

The shrub layer is dominated by either, or both, *Ribes wolfii* and *R. montigenum*. A rich, well-expressed herbaceous layer is dominated by *Senecio sanguisorboides*. Other common species are *Ligusticum porteri*, *Osmorhiza depauperata*, *Actaea arguta*, *Bromus richardsonii*, *Trisetum montanum*, *Festuca sororia*, *Pseudocymopteris montanus*, and *Erigeron superbus*.

Although there possibly may be two phases in this habitat type, they have not been designated as such because of the overall homogeneity of vegetation and the limited distribution of spruce-fir forests in the Sierra Blanca area (Dye and Moir 1977). A typical phase could be found on most sites, whereas the *Pseudotsuga menziesii* phase (stands containing *P. menziesii*) would be restricted to warmer sites at low elevations. In contrast to the typical phase, the *Pseudotsuga* phase exhibits low coverage values of *Ribes*, and *Populus tremuloides* may form a seral community in some locations. In the more typical situation, *Ribes montigenum* and *R. wolfii* increase in abundance, and especially dominate large fire-created openings; *Pseudotsuga* and often *Populus tremuloides* are absent.

Physical setting.—The habitat type is common to the Sacramento Mountains in the vicinity of Sierra Blanca Peak, and is found on all slopes and aspects above 10,000 feet (3,050 m). Soils have developed mostly from Three Rivers material, intrusive monzonite and granite. Soils are primarily Typic and Pachic Cryoborolls, with coarse-loamy texture and good drainage; profiles are deep and have A1-A3-C mineral horizon sequences. Cob-

Table 1.—List of habitat types and phases on the Lincoln National Forest

Habitat name	Abbreviation	Number of plots
Abies lasiocarpa series		
Abies lasiocarpa/Senecio sanguisorboides habitat type[1]	ABLA/SESA HT	9
Picea engelmannii series		
Picea engelmannii/Acer glabrum habitat type[1]	PIEN/ACGL HT	2
Picea engelmannii/Elymus triticoides habitat type[1]	PIEN/ELTR HT	4
Picea pungens series		
Picea pungens/Fragaria ovalis habitat type	PIPU/FROV HT	5
Abies concolor series		
Abies concolor/Acer grandidentatum habitat type	ABCO/ACGR HT	
Acer grandidentatum typic phase	ACGR typic P	3
Holodiscus dumosus phase	HODU P	3
Abies concolor/Elymus triticoides habitat type[1]	ABCO/ELTR HT	4
Abies concolor/Acer glabrum habitat type	ABCO/ACGL HT	
Holodiscus dumosus phase[1]	HODU P	17
Abies concolor/Quercus gambelii habitat type	ABCO/QUGA HT	
Quercus gambelii typic phase[1]	QUGA typic P	18
Holodiscus dumosus phase[1]	HODU P	7
Festuca arizonica phase[1]	FEAR P	4
Muhlenbergia virescens phase[1]	MUVI P	1
Muhlenbergia dubia phase	MUDU P	2
Abies concolor/Sparse undergrowth habitat type[1]	ABCO/Sparse HT	1
Abies concolor/Juglans major habitat type	ABCO/JUMA HT	4
Pseudotsuga menziesii series		
Pseudotsuga menziesii/Quercus gambelii habitat type	PSME/QUGA HT	
Quercus gambelii typic phase	QUGA typic P	9
Holodiscus dumosus phase	HODU P	6
Pinus ponderosa series		
Pinus ponderosa/Quercus gambelii habitat type	PIPO/QUGA HT	2
Pinus ponderosa/Quercus undulata habitat type	PIPO/QUUN HT	
Quercus undulata typic phase	QUUN typic P	7
Muhlenbergia dubia phase	MUDU P	8
Muhlenbergia longiligula phase	MULO P	2

[1]*Previously described by Moir and Ludwig (1979).*

bles may be very compact below about 12–18 inches (30–45 cm) (Dye and Moir 1977).

Ecotones and adjacent habitats.—Ecotones occur with alpine tundra along high, windswept ridges (Moir and Smith 1970) and with meadows dominated by *Festuca thurberi* (Moir 1967). At lower elevations, mixed conifer forests consist mostly of the *Abies concolor/Acer glabrum* habitat type, *Holodiscus dumosus* phase.

Discussion.—This habitat type is situated in a zone of high precipitation, much of which is in the form of snow, and as a consequence, recreational skiing is extensive. The ABLA/SESA HT also serves as the principal watershed for the towns of Ruidoso and Capitan, N. Mex.

This habitat type exhibits high site quality for *Abies lasiocarpa* var. *arizonica*. Robust, long-lived ecotypes and the tallest known specimens grow here, and some individuals often are older than 275 years. Such longevity may explain the higher density of mature *Abies* in this type than in most other spruce-fir habitat types in Arizona and New Mexico. An examination of the structure of six mature stands indicated that the major climax species in four stands was *A. lasiocarpa* var. *arizonica*, whereas both *Abies* and *Picea engelmannii* occupied the remaining two stands.

According to Dye and Moir (1977), there is no evidence that the majority of adjoining *Fescue thurberi* meadows are fire-initiated precursors of spruce-fir forests. Rather, they appear to be edaphic climaxes on soils that are more finely textured than forest soils (Moir 1967), and may have originated during warmer postglacial climates as forests retreated upward in elevation and grassland vegetation followed.

Picea engelmannii Series

Picea engelmannii/Acer glabrum habitat type (PIEN/ACGL; Engelmann spruce/Rocky Mountain maple) (from Moir and Ludwig 1979)

Disjunct outliers of *Picea engelmannii* are found in the Hubbell and Sacramento Canyons of the Sacramento

Mountains and in the Chiricahua Mountains of Arizona. While these outliers were assigned to the *Picea engelmannii/Acer glabrum* habitat type, they are not sufficiently widespread in occurrence to consider the type of major importance on the Lincoln National Forest. *Pseudotsuga menziesii* is the most important codominant tree, and *Acer glabrum* is usually present in the understory. Herbaceous cover in plots ranged from 5% to 17%, with the most constant species being *Bromus richardsonii*, *Viola canadensis*, *Smilacina stellata*, and *Ligusticum porteri*. The habitat type is of interest primarily because Engelmann spruce is present at low elevations (8,900–9,200 feet or 2,710–2,800 m) at its southernmost limit in North America (Chiricahua Mountains, Arizona, lat. 31°52′ N.).

Picea engelmannii/Elymus triticoides habitat type (PIEN/ELTR; Engelmann spruce/beardless wild rye) (from Moir and Ludwig 1979)

This habitat type, also considered minor, is restricted to the Capitan Mountains at uppermost elevations. *Pseudotsuga menziesii* is codominant; *Abies lasiocarpa* varies from absent to codominant. A shrubby undergrowth varying in cover density from 2% to 23% consists of *Acer glabrum*, *Holodiscus dumosus*, *Jamesia americana*, and *Ribes* spp. Soils are very cobbly, and undergrowth vegetation appears to be related to the buildup of soils, commencing from raw talus. On better developed soils, *Elymus triticoides* may cover up to about 20% of the surface.

MIXED CONIFER HABITAT TYPES

Picea pungens Series

Picea pungens/Fragaria ovalis habitat type (PIPU/FROV; Colorado blue spruce/wild strawberry)

Vegetation.—*Picea pungens* and *Pseudotsuga menziesii* are codominants in this habitat type (fig. 4), each with a density of between 60 and 80 square feet of basal area per acre (13.8 and 18.4 m^2/h). *Abies concolor* is nearly always present, but only as a minor climax species. *Picea engelmannii* may be present in small amounts, while *Pinus strobiformis* and *P. ponderosa* are rare components. *Populus tremuloides* is the major successional species following fire and other major disturbances.

The shrub layer is highly variable, with *Holodiscus dumosus* and *Acer glabrum* being the most common, but exhibiting little constancy. Often, the shrub component is absent.

Poa pratensis, *Bromus richardsonii*, and *Trisetum montanum* are the three dominant grasses of this habitat type. Coverage of these species may be high—over 80% of the plot—but the grass component is less consistent than the forb layer. *Fragaria ovalis* and *F. bracteata* are consistent species in the undergrowth, which is usually dominated by forbs. Other forbs include

Figure 4.—*Picea pungens/Fragaria ovalis* habitat type. Plot 855, Cox Canyon, Lincoln National Forest (8,400 feet or 2,560 m). *Pseudotsuga menziesii* codominant with Picea pungens; Abies concolor common. *Holodiscus dumosus* and *Acer glabrum* often present; *Poa pratensis* also common.

Cystopteris fragilis, *Galium asperrimum*, *Dugaldia hoopesii* (*Helenium hoopesii*), *Iris missouriensis*, *Oxalis alpina*, and *Pseudocymopteris montanus*.

Physical setting.—All plots sampled in this habitat type were found in the Sacramento Mountains. The habitat type is restricted to sideslopes near canyon bottoms, at elevations between 8,000 and 9,000 feet (2,440 and 2,745 m) and always on northern exposures. Soils have well-developed litter and duff layers.

Ecotones and adjacent habitats.—A meadow community dominated by *Poa pratensis* can be found in canyon bottoms directly below the PIPU/FROV HT. It is doubtful, however, that the streamside *Picea pungens/Poa pratensis* (PIPU/POPR) habitat type occurs here as suggested by Moir and Ludwig (1979). Extensive reconnaissance subsequent to their study has not revealed the PIPU/POPR HT, except possibly as a very narrow ecotone at the forested edge of the meadows.

Pseudotsuga menziesii increases within the PIPU/FROV HT further upslope from the canyon bottom, and is indicative of the *Picea pungens-Pseudotsuga menziesii* habitat type described by Moir and Ludwig (1979) on the Lincoln National Forest. As with the PIPU/POPR HT, however, additional studies reported here and elsewhere in Arizona and New Mexico (Fitzhugh et al.,[8] Alexander et al.,[9] DeVelice et al.[10]) show that such stands should be considered ecotones and not habitat types. These ecotones lie between the PIPU/FROV HT and the *Abies concolor* series habitat types, commonly the *Abies concolor/Acer glabrum* habitat type, *Holodiscus dumosus* phase.

Discussion.—The *Picea pungens* series is highly restricted on the Lincoln National Forest, occurring only in cool, moist canyons at mid-elevations. Because of acces-

[9] *Billy G. Alexander, Jr., E. Lee Fitzhugh, John A. Ludwig, and Frank Ronco, Jr. Forest habitat types of the Cibola National Forest, New Mexico. Manuscript in preparation.*

[10] *Robert L. DeVelice, John A. Ludwig, William H. Moir, and Frank Ronco, Jr. A classification of forest habitat types in northern Mexico and southern Colorado. Manuscript in preparation.*

sibility, these sites historically have been heavily grazed and subsequently subjected to considerable disturbance. Consequently, sampling this series for climax or near-climax stands was difficult, and only seven plots were sampled between this study and that of Moir and Ludwig (1979). All known *Picea pungens* stands, however, were sampled by the two studies.[11]

A larger sample from the Gila National Forest established the existence of several *Picea pungens* habitat types that are characterized by an abundant grass cover or a dominant forb layer (Fitzhugh et al.[8]). In the Lincoln National Forest, the PIPU/FROV HT identified in this study is clearly forb-dominated and similar to that described on the Gila National Forest by the above authors. DeVelice et al.[10] recognized shrub- and grass-dominated *Picea pungens* habitat types in northern New Mexico. The Cibola National Forest also has shrub-dominated *Picea pungens* habitat types—*Picea pungens/Cornus stolonifera*—as well as those of a grass-dominated nature—*Picea pungens/Carex foenea* habitat type (Alexander et al.[9]). The Lincoln National Forest, in contrast, lacks the diversity shown in these other areas.

The *Picea pungens* habitat types and communities on the Lincoln National Forest are heavily impacted by humans. Their restriction to mid-elevation, cool, moist canyons and close proximity to water results in heavy use from recreation and livestock activities. The *Picea pungens* forest also is used extensively by wildlife for feeding and traveling between canyon bottoms and the remainder of the forest. Trees in these canyon bottom communities are sparse, with only an occasional individual *Picea pungens* present. The undergrowth composition reflects the high degree of disturbance, with *Poa pratensis* and other indicator species such as *Erodium cicutarium* and *Artemisia dracunculus* being common.

In the ecotone situated above the PIPU/FROV HT, common plants are *Pseudotsuga menziesii, Acer glabrum*, and *Holodiscus dumosus*. These species are representative of both the habitat type and the ecotone, but coverage increases with increasing upslope distance from the canyon bottom. The ecotone, however, is absent or minor when ecological boundaries, such as those delineated by cold air drainages, are abrupt, but may be extensive in areas where the environmental change is gradual.

Abies concolor Series

Abies concolor/Acer grandidentatum habitat type (ABCO/ACGR; white fir/big tooth maple)

Vegetation.—*Abies concolor* is the primary timber species in the climax community of this habitat type (fig. 5). *Pseudotsuga menziesii* is late successional, but it can occur in climax stands. In younger stands, it is much more numerous. Furthermore, these young stands have dense *Abies concolor* regeneration. *Pinus strobiformis* is always of minor importance in stands of this habitat type, but is commonly present. In contrast, other timber species, notably *Pinus ponderosa*, are absent.

Figure 5.—*Abies concolor/Acer grandidentatum* habitat type, *Holodiscus dumosus* phase. Plot 839, Baily Canyon, Lincoln National Forest (8,440 feet or 2,570 m). *Pseudotsuga menziesii* a prominent member of overstory; *Abies concolor* dominant. *Acer glabrum* present in tree form. Rod graduated in decimeter segments.

The diagnostic tall shrub is *Acer grandidentatum*, which is always present in contrast to the usual absence of *Acer glabrum*. If present, *A. glabrum* will be subordinate to *A. grandidentatum*, and may represent an ecotone between the ABCO/ACGR HT and the ABCO/ACGL HT. Stands with a high coverage of *A. grandidentatum*, reaching 60% in some instances, often have a relatively low coverage of conifer species. *Quercus gambelii* is always present, but coverage is low.

The number of different forbs comprising the undergrowth of this habitat type is indicative of its cool, moist nature. *Thalictrum fendleri* is most common, followed by *Galium boreale* and *Smilacina stellata*. Of interest is the frequent occurrence of *Habenaria sparsiflora*.

***Acer grandidentatum* (ACGR) typic phase.**—This phase represents the drier component of the habitat type, with *Holodiscus dumosus* absent. *Bromus richardsonii* and *Carex* spp. are common.

***Holodiscus dumosus* (HODU) phase.**—In contrast to the typic phase, the HODU phase is found on wetter sites of the habitat type. It is characterized by the presence of the diagnostic species *Holodiscus dumosus*. *Bromus richardsonii* is the only graminoid found in this phase.

Physical setting.—The ABCO/ACGR HT is always found in canyons or similar cool, moist sites. Elevation varies from 6,500 feet (1,980 m) to more than 8,500 feet (2,590 m), with the *Holodiscus dumosus* phase found above 7,500 feet (2,285 m). This habitat type is generally found on northern aspects, but if conditions are sufficiently mesic, it can be found on western and eastern exposures as well.

Ecotones and adjacent habitats.—At lower elevations, steep canyons can result in abrupt environmental

[11]*Personal communication with Timber Staff personnel, USDA Forest Service, Lincoln National Forest, 1979.*

changes. In such situations, the community adjacent to the *Abies concolor/Acer grandidentatum* habitat type may be the *Pseudotsuga menziesii/Quercus gambelii* habitat type or even the *Pinus ponderosa/Quercus gambelii* habitat type. Where slopes are more gradual, the adjacent community often is the mesic *Abies concolor/ Acer glabrum* habitat type, *Holodiscus dumosus* phase.

Discussion.—The ABCO/ACGR HT, at its representative elevation, is the most mesic habitat type of the *Abies concolor* series. It is a highly restricted type, being confined to the lower portion of slopes rising from canyons. Moir and Ludwig (1979) also defined a canyon streamside ABCO/ACGR HT in Arizona that appears to reflect virtually the same forest and environmental conditions recognized here.

Abies concolor/Elymus triticoides habitat type (ABCO/ELTR; white fir/beardless wild rye) (from Moir and Ludwig 1979)

This habitat type is unique and is limited to the Capitan Mountains where it borders the *Picea engelmannii/Elymus triticoides* habitat type. *Abies concolor* and *Pseudotsuga menziesii* dominate. *Pinus strobiformis* usually is abundant but not dominant, and at times will be absent. *Picea engelmannii* is absent, while other timber species are rarely found. Common tall shrubs are *Quercus gambelii* and *Holodiscus dumosus*; *Acer glabrum* is absent. The undergrowth is dominated by grasses. *Elymus triticoides* is very abundant, covering up to 80% of a stand. *Bromus richardsonii* also is common, but not as abundant as *E. triticoides*. The forb undergrowth is minimal; no species is constant. This habitat type is within the group of mixed conifer habitats characterized by grass-dominated undergrowth, such as the Abies concolor/Quercus gambelii and the *Abies concolor/Festuca arizonica* habitat types. Soils are extremely cobbly, and grass cover is interrupted by patches of cobbly talus at the surface.

Abies concolor/Acer glabrum habitat type (ABCO/ACGL; white fir/Rocky Mountain maple)

Vegetation.—*Abies concolor* dominates in stands of this habitat type (fig. 6), if not in the overstory then as regeneration. *Pseudotsuga menziesii* is a successional dominant, and it remains a codominant in climax stands, becoming minor in very old stands. *Pinus strobiformis* is similar to *Pseudotsuga menziesii* in behavior, but will not maintain codominant status in older stands. *Pinus ponderosa* occasionally may be present in this habitat type.

The tall shrub layer is highly diagnostic of this habitat type. *Acer glabrum* is always present, ranging from high to low coverage. In the one phase of the habitat type recognized on the Lincoln National Forest, *Holodiscus dumosus* is always present. *Quercus gambelii* is a common component, but when present, always has low coverage values. *Symphoricarpos oreophilus*, while sometimes present, has little diagnostic value.

Figure 6.—*Abies concolor/Acer glabrum* habitat type, *Holodiscus dumosus* phase. Plot 840, Baily Canyon, Lincoln National Forest (8,280 feet or 2,525 m). *Abies concolor* and *Pseudotsuga menziesii* dominate these sites; *Pinus strobiformis* common, *Pinus ponderosa* uncommon. *Acer glabrum* and *Holodiscus dumosus* always present.

The only grass of any abundance is *Bromus richardsonii*, which is a common component of the undergrowth. Predominant forbs include *Galium boreale*, *Stellaria longifolia*, and *Thalictrum fendleri*, which can be sufficiently abundant to cover a large percentage of the site.

***Holodiscus dumosus* (HODU) phase.**—This phase is the only form in which the ABCO/ACGL HT occurs on the Lincoln National Forest, and it is characterized by the presence of *Holodiscus dumosus*.

Physical setting.—The ABCO/ACGL HT, HODU phase is found predominantly on north- and northwest-facing slopes, and possibly on more westerly slopes where sites are wet and cool. Its elevational range is broad—from 8,000 feet (2,440 m) to more than 9,500 feet (2,895 m). Where it lies at lower elevations, sites will be locally wet and cool. Therefore, the type is located along canyon sides and cool drainages, and its presence is most striking in cool drainages where the adjacent community may be much drier. At upper elevations, this habitat type occurs along the tops of ridges and knolls. Soils were derived from alluvial deposits or sideslope colluvial parent materials, and the litter layer usually was well developed.

Ecotones and adjacent habitats.—At upper elevations, this habitat type forms ecotones with spruce-fir types. Where environmental conditions are too dry for optimum development of the type, the resulting ecotone will be shared with the adjacent *Abies concolor/Quercus gambelii* habitat type, *Holodiscus dumosus* phase. In contrast, the *Abies concolor/Acer grandidentatum* habitat type will be found adjacent to the ABCO/ACGL HT, HODU phase, in cool, wet drainages where conditions are especially moist.

Discussion.—This habitat type and associated phase are found in cool, wet sites, and are well represented on the Lincoln National Forest, especially in the Sacramento Mountains. Moir and Ludwig (1979) also described this habitat type and phase as well as a *Berberis repens* phase found in northern New Mexico and an outlier in the White Mountains of Arizona. Hanks (1966) studied successional relationships in the *Holodiscus dumosus* phase and concluded that fire was the principal factor initiating succession. Because of wet conditions existing in mixed conifer forests, historical fires were infrequent, generally light, and erratic. But localized intense fires probably resulted in a patchy or mosaic stand structure (Jones 1974). Logging and stand deterioration with increasing age, however, also contributed to the irregular structure.

While *Quercus gambelii* and *Robinia neomexicana* follow the herbaceous stage and dominate burned-over areas a few years after fires, other important species such as *Acer glabrum*, *Holodiscus dumosus*, and *Ptelea trifoliata (P. angustifolia)* also are found in the shrub stage (Moir and Ludwig 1979). In the late coniferous stage of succession, *Abies concolor*, *Pseudotsuga menziesii*, and *Pinus strobiformis* become established. *Pinus ponderosa*, however, is present only occasionally, apparently becoming established in small openings created by hot fires.

Abies concolor/Quercus gambelii habitat type (ABCO/QUGA; white fir/Gambel oak)

Vegetation.—*Abies concolor* and *Pseudotsuga menziesii* are the principal climax timber species of this habitat type, but as the stand matures, the dominant *P. menziesii* is replaced by the more shade tolerant *Abies concolor*. On drier sites of this habitat type, *Pseudotsuga menziesii* maintains itself in a prominent climax role. *Pinus ponderosa* and *P. strobiformis* are common seral trees, but distribution of the latter is highly variable, being much more prominent on wetter than drier sites. Furthermore, it is often absent from older, near-climax stands. Occasional individual *Pinus edulis* and *Juniperus deppeana* trees also can be found on drier sites, especially on those areas where the habitat type grades directly into pinyon-juniper sites.

Quercus gambelii is the prominent shrub component of this forest type, with coverage values up to 5% or greater. Large clumps of *Quercus gambelii* found on these sites may be due to past disturbances, such as local concentrations of heat in widespread burns, which especially favored oak regeneration. *Robinia neomexicana* also may be abundant on disturbed sites.

Grasses of this habitat type are more diverse than those of the wetter ABCO/ACGL HT, but they may be sparse, or nearly absent, or codominant with *Q. gambelii*, depending on the phase of the habitat type. *Bromus richardsonii*, *Festuca arizonica*, and *Poa fendleriana* are encountered most often; other grasses range from the mesic *Elymus triticoides* to the more xeric *Muhlenbergia virescens* and *M. dubia*. *Carex rossii* also is found frequently. Forbs are highly variable, with *Thalictrum fendleri* present on most sites. *Clematis ligusticifolia* is common in the *Holodiscus dumosus* phase of the type.

Figure 7.—*Abies concolor/Quercus gambelii* habitat type, *Holodiscus dumosus* phase. Plot 837, Cloudcroft Experimental Forest, Lincoln National Forest (8,600 feet or 2,620 m). *Abies concolor* dominant; *Pseudotsuga menziesii* often codominant. *Holodiscus dumosus* and *Quercus gambelii* abundant; forbs with high diversity.

***Quercus gambelii* (QUGA) typic phase.**—With the exception of *Quercus gambelii* (to which grasses are subordinate), the typic phase of the ABCO/QUGA HT is characterized by a lack of any adequate diagnostic species. However, *Poa fendleriana* increases as the stand nears the climax stage.

***Holodiscus dumosus* (HODU) phase.**—The HODU phase (fig. 7) is characterized by the presence of *Holodiscus dumosus*, which may cover as much as 25% of a given site. *Quercus gambelii* still has a high coverage. *Symphoricarpos oreophilus* and *Clematis ligusticifolia* also are common components of this type.

***Festuca arizonica* (FEAR) phase.**—*Festuca arizonica* is the diagnostic species of this phase, with coverage values up to 20%. *Muhlenbergia montana* and *Poa fendleriana* are common. The FEAR phase lacks forb diversity, but *Erigeron platyphyllus*, *Geranium caespitosum*, and *Artemisia ludoviciana* are common. This phase of the habitat type is not widespread on the Lincoln National Forest.

***Muhlenbergia virescens* (MUVI) phase.**—This phase (fig. 8) is delineated by the presence of *Muhlenbergia virescens*, which may have up to 60% cover in some areas according to Moir and Ludwig (1979). In addition, Moir and Ludwig indicated that *Stipa pringlei* and *Sitanion hystrix* may be common, depending on location. Similarly, *Festuca arizonica*, *Poa fendleriana*, *P. interior*, and *Koeleria pyramidata (K. cristata)* may be present, but in minor amounts. They also indicated that the following forbs occasionally may be important: *Pteridium aquilinum*, *Thermopsis pinetorum*, and *Vicia pulchella*.

Overall acreage of this phase is low, and in addition, its distribution is somewhat limited on the Lincoln National Forest.

***Muhlenbergia dubia* (MUDU) phase.**—Of all the types in the *Abies concolor* series, the MUDU phase of the ABCO/QUGA HT is the most xeric. It is distinguished by the presence of *Muhlenbergia dubia*, and is restricted to cool canyons at low elevations. *Pinus ponderosa* increases in abundance on sites where this phase is found. Topographic sites that favor this phase are common in the Capitan Peak area.

Physical setting.—The habitat type ranges in elevation from 6,500 feet (1,980 m) to more than 9,000 feet (2,745 m) on all aspects and a variety of topographical positions, depending on the phase. The MUDU phase is generally restricted to north to northeast slopes or cool canyon bottoms on north-facing mountain sides and, at 6,500 to 7,000 feet (1,980 to 2,135 m), is the lowest representative of the type.

In contrast, the typic and HODU phases starting at 7,000 feet (2,135 m) are the highest, and may extend to above 9,000 feet (2,745 m). The typic phase may be found on most aspects of upper canyons and ridge tops, whereas the HODU phase is found on north and northwest slopes below 8,000 feet (2,440 m) and on east slopes as well at higher elevations. Typically, the HODU phase occupies canyon slopes and, occasionally, upper ridge slopes.

The MUVI phase occupies an elevational range from 7,000 to 8,500 feet (2,135 to 2,590 m) or more. At higher elevations, sites occupied by the phase are typically south facing, tending towards cooler east aspects as elevation decreases.

The various phases of this habitat type may be related, in part to the wide variation of soil parent materials, stoniness, and depth. These relationships, however, are not clear at the present time.

Figure 8.—*Abies concolor/Quercus gambelii* habitat type, *Muhlenbergia virescens* phase. Plot 821, Mill Canyon, Lincoln National Forest (8,660 feet or 2,640 m). This plot exemplifies the young mixed conifer understory with a *Pinus ponderosa* overstory. *Muhlenbergia virescens* a dominant grass.

Ecotones and adjacent habitats.—According to Moir and Ludwig (1979), the typic phase probably is characterized by moderate regimes of temperature and moisture with respect to the environmental gradient within mixed conifer forests. Under more moist situations, the HODU phase is the most prominent adjacent community, but any of the more mesic habitat types also may occupy a similar position. In turn, the HODU phase is bordered by the more mesic ABCO/ACGL HT (HODU phase), with the ecotone between the two types recognized by a decrease in *Quercus gambelii* and an increase in *Acer glabrum*. Furthermore, many areas occupied by the HODU phase are spatially narrow because of sharp local topographical differences. Under certain instances where site conditions are not limiting, the typic phase may be bordered by the MUVI or MUDU phases of the ABCO/QUGA HT.

As sites occupied by the typic phase gradate toward drier conditions, the existing vegetation is replaced by more xeric associations such as the PSME/QUGA HT or various habitat types of the *Pinus ponderosa* series. It also may be bordered on the drier fringes by the MUDU, MUVI, and FEAR phases of the ABCO/QUGA HT. Under restricted topographical conditions, the MUDU phase can lie adjacent to pinyon-juniper woodlands, and as a consequence, it is the lowest elevational representative of the *Abies concolor* series.

Discussion.—The ABCO/QUGA HT had been described previously by Moir and Ludwig (1979), who recognized the typic and two other phases—*Muhlenbergia virescens* and *Festuca arizonica*. Two additional phases, *Holodiscus dumosus* and *Muhlenbergia dubia*, were defined by this study.

Not only is the ABCO/QUGA HT the most extensive habitat type on the Lincoln National Forest, but its widespread distribution and utilization make it an important type throughout the Southwest. According to Moir and Ludwig (1979), most of the type lies in commercial forests and also within grazing allotments. In addition, deer and other wildlife benefit from oaks and other undergrowth species. Its division into phases reflects shifts in the complex environmental factors to which the plant association responds. The HODU phase lies at the mesic end of the moisture gradient, while the MUVI, FEAR, and MUDU phases represent more xeric conditions for this type. Although the relative dominance between various grasses and oak in different phases of the type is not readily explained, the cause may be related to soil variability, especially in regard to rooting volume and stoniness (Moir and Ludwig 1979).

This habitat type exemplifies low-elevation *Abies concolor* forests, as evidenced by sites on the Lincoln National Forest where *A. concolor* grades into pinyon-juniper woodlands. These areas are occupied by the MUDU phase of the habitat type. The two xeric phases of the habitat type, MUVI and MUDU, are not extensive on the Forest, and as a consequence, data from these areas were limited. Further research is needed to refine and more clearly define these two phases.

***Abies concolor*/Sparse undergrowth habitat type (ABCO/Sparse; white fir/sparse)**

Vegetation.—This type is characterized by an overstory that may contain *Abies concolor, Pseudotsuga menziesii, Pinus strobiformis,* and *P. ponderosa,* with a very sparse herbaceous undergrowth—mostly less than 1%, but occasionally to 15% coverage. Moir and Ludwig (1979) observed the *Robinia neomexicana* phase of this habitat type in the southern half of New Mexico, which would include the Lincoln National Forest. Undergrowth species present in the Lincoln, although sporadic, are: *Robinia neomexicana, Symphoricarpos oreophilus, Salix scouleriana,* and *Quercus gambelii.*

Physical setting.—The ABCO/Sparse HT is common on north to east aspects at elevations of 8,000 to 9,000 feet (2,440 to 2,745 m). It may occur at higher elevations on south- to west-facing aspects. This habitat type is typical of cool, dry sites.

Ecotones and adjacent habitats.—On drier sites, the *Abies concolor/Quercus gambelii* or the *Pseudotsuga menziesii/Quercus gambelii* habitat types may be present at the ecotone. At cooler, wetter borders of this habitat type, stands of spruce-fir forest are found.

Discussion.—Further work is needed to establish the extent of the *Abies concolor*/Sparse undergrowth habitat type on the Lincoln National Forest. Moir and Ludwig (1979) identified the habitat type on the Forest, but their sample was limited. No new stands of this habitat type were found on the Forest during this study. Whether the *Robinia neomexicana* phase or possibly the *Berberis repens* phase occurs here is difficult to determine because of limited data. Fitzhugh et al.[8] found the *Robinia neomexicana* phase of the habitat type on the Gila National Forest, while DeVelice et al.[10] recognized the *Berberis repens* phase in northern New Mexico. The geographical distinction between the two phases is consistent with the conclusions of Moir and Ludwig (1979). Site quality in this habitat type may be poor to moderate, according to the latter authors.

***Abies concolor/Juglans major* habitat type (ABCO/JUMA; white-fir/Arizona walnut)**

Vegetation.—*Abies concolor* is the dominant climax timber species of this habitat type (fig. 9). *Populus angustifolia,* while nearly always present, varies in dominance; it is sometimes represented only by one or two trees covering large areas of any given plot. *Acer negundo* will be present, but not as a canopy dominant. *Fraxinus pennsylvanica* also is a stand component, being more strongly represented in younger age classes. Although *Juglans major* is only a minor constituent of the overstory, its presence is diagnostic.

Quercus gambelii is not only a common species in this habitat type, but it is sometimes quite abundant considering the riparian nature of the vegetation. *Vitis arizonica* is a common component of the shrub layer. The density of *Poa pratensis,* the only grass of consequence found in this habitat type, was quite high on

Figure 9.—*Abies concolor/Juglans major* habitat type. Plot 845, Three Rivers Canyon, Lincoln National Forest (7,100 feet or 2,165 m). *Abies concolor* the climax timber species; *Populus angustifolia* also prominent in overstory. *Juglans major* common along with *Quercus gambelii* and *Vitis arizonica.*

some plots. Few forbs show any constancy whatsoever, and the only one to be found on all sites is *Thalictrum fendleri.*

Physical setting.—The ABCO/JUMA HT, a streamside, canyon type, is found only in riparian areas on stream benches. It is well represented near 7,000 feet (2,135 m) elevation, but may occur at lower elevations. Aspect does not seem to be a determinant of location; rather, water and shade probably are the controlling factors.

Sample stands of this type were found on soils of alluvial origin. The soils observed were very rocky and sandy with a low organic matter component because of frequent flooding and high stream flows.

Ecotones and adjacent habitats.—The ABCO/JUMA HT is restricted to water courses that traverse many different vegetational zones as elevation changes. As a consequence, a variety of habitat types may be found adjacent to the ABCO/JUMA HT. In lower elevations, the type can border pinyon-juniper woodlands. With increasing elevation, *Pinus ponderosa* and *Pseudotsuga menziesii* habitat types appear beside this riparian type. Finally, as the stream-course sites become even cooler with additional elevational increases, the ABCO/JUMA HT is replaced by other *Abies concolor* habitat types, either the ABCO/ACGR HT or the ABCO/ACGL HT. Ecotones involving this habitat type are quite abrupt and narrow because of the corresponding abrupt change in the availability of water over short distances from the stream course.

Discussion.—The ABCO/JUMA HT is a typical riparian habitat type that is quite restricted because an adequate water supply is often lacking locally. Furthermore, the sparseness of stream courses on the Lincoln National Forest also limits distribution.

However, the habitat type, when present, provides excellent habitats for wildlife, especially birds, and may

be a critical habitat component for mammals with daily ranges that extend beyond the boundaries of the type. Snags, particularly *Populus angustifolia*, provide good nesting sites for many species. Because of its association with stream courses and the dense canopy that ameliorates the microclimate, the habitat type is used quite heavily by wildlife seeking water and thermal protection.

Pseudotsuga menziesii Series

Pseudotsuga menziesii/Quercus gambelii habitat type (PSME/QUGA; Douglas-fir/Gambel oak)

Vegetation.—*Pseudotsuga menziesii* is the dominant climax tree species of this habitat type (fig. 10), whereas *Abies concolor* is conspicuously absent. *Pseudotsuga menziesii* is much more abundant than in habitat types of the *Abies concolor* series, as evidenced by more regeneration under the canopy. *Pinus strobiformis* can be considered subclimax because it is abundant, although it is more variable than *Pseudotsuga menziesii*. Successionally, *Pinus ponderosa* forms a disclimax in this habitat type because of its adaption to fire. Many climax stands show evidence of old fire-scarred *P. ponderosa* being replaced by *Pseudotsuga menziesii* and *Pinus strobiformis*. No regeneration of *Pinus ponderosa* can be seen in the understory. On many drier sites, *P. ponderosa* may become late successional, bordering on a climax element. Also in drier, low-elevation sites, *Pinus edulis* may be present, primarily in the regeneration age class. However, it probably does not play a role in the *P. ponderosa* disclimax because a fire frequency that limits establishment of *Pseudotsuga menziesii* may have a similar effect on *Pinus edulis*. It also is not found in climax stands represented by this habitat type. In addition to *P. edulis*, *Juniperus deppeana* is occasionally found on drier sites.

***Quercus gambelii* (QUGA) typic phase.**—*Quercus gambelii* is the dominant tall shrub species, with an areal coverage of up to 30% in some plots. A slight increase in diversity of shrubs was noticed at lower elevation sites; especially common were *Cercocarpus montanus* and *Rhus trilobata*. The number of grass species increases in this habitat type over that found in the *Abies concolor* series. *Bromus richardsonii* is a common species, while other species of a sporadic nature include *Poa fendleriana*, *Muhlenbergia pauciflora*, *Sitanion hystrix*, and *Stipa pringlei*. Forbs found in the type are characteristic of more mesic sites; *Chaptalia alsophila* is common, but *Galium boreale*, *Lathyrus arizonicus*, and *Pseudocymopterus montanus* also can be expected in the undergrowth.

***Holodiscus dumosus* (HODU) phase.**—Because of its more mesic character, this phase of the habitat type has fewer *Pinus ponderosa*, especially in older stands. *Pinus edulis* is only accidental, and *Juniperus deppeana* is rare. *Holodiscus dumosus* is diagnostic for delineating the phase, but *Quercus gambelii* is still quite abundant and always intermixed with *Holodiscus dumosus*. Generally, the diversity of grasses decreases in this phase—

Figure 10.—*Pseudotsuga menziesii/Quercus gambelii* habitat type, *Holodiscus dumosus* phase. Plot 860, Wet Burnt Canyon, Lincoln National Forest (7,280 feet or 2,220 m). *Abies concolor* absent, *Pseudotsuga menziesii* dominant, *Pinus strobiformis* and *Pinus ponderosa* common particularly on seral sites; *Quercus gambelii* the dominant shrub.

Bromus richardsonii is quite constant, while other species are rare. Forbs increase in both diversity and constancy; *Chaptalia alsophila*, *Cystopteris fragilis*, *Galium boreale*, *Geranium caespitosum*, *Pseudocymopterus montanus*, *Senecio sacramentanus*, *Smilicina* spp., and *Thalictrum fendleri* can be expected in the herbaceous layer.

Physical setting.—Both the QUGA- typic and HODU phases can be found on canyon sideslopes and ridgetops at elevations ranging from 7,200 to 8,500 feet (2,195 to 2,590 m). The *Holodiscus dumosus* phase is situated on northwest to northeast aspects, whereas the typic phase is not limited to any particular aspect. In many cases, the organic layer at the mineral soil surface was poorly developed, and sites were rocky.

Ecotones and adjacent habitats.—At higher elevations, the habitat type may occur as a pocket within habitat types of the *Abies concolor* series, while dry south slopes may exhibit the typic phase, which commonly borders *Pinus ponderosa* habitat types at lower elevations. The *Holodiscus dumosus* phase borders *Abies concolor* habitat types and at lower elevations is found on north-facing slopes. Because this single habitat type of the *Pseudotsuga* series borders habitat types of two other distinct series, the transition often is obvious; decreasing densities of *Abies concolor* and *Pinus ponderosa* as climax species at higher and lower elevations, respectively, signify the change in habitat.

Discussion.—Because of increased exclusion of fire, vegetation in the habitat type is approaching a climax state and, as a result of higher stocking densities, competition between climax *Pseudotsuga menziesii* and seral *Pinus ponderosa* most likely has intensified. As a consequence, the productivity of *Pinus ponderosa* prob-

ably is lowered. The increased fire hazard from heavier fuel accumulations has been discussed earlier.

It is noteworthy that the habitat type is absent from certain localities on the Forest. Large areas on the eastern slope of the Sacramento Mountains are covered by this habitat type, but northern flanks of mountains elsewhere on the Lincoln generally do not exhibit such large areas of the PSME/QUGA HT. These geographical differences in distribution probably are related to climatic variations attributable to topographical differences.

PONDEROSA PINE HABITAT TYPES

Pinus ponderosa Series

Pinus ponderosa/Quercus gambelii habitat type (PIPO/QUGA; ponderosa pine/Gambel oak)

Vegetation.—*Pinus ponderosa* is the dominant climax timber species in the PIPO/QUGA HT (fig. 11), while all other mixed conifer species are absent, with the exception of the rare occurrence of *Pseudotsuga menziesii* and *Pinus strobiformis*. *Pinus edulis* and *Juniperus deppeana* are common, but are not dominant elements of the overstory.

Quercus gambelii is the only shrub that consistently grows in this habitat type, often forming dense clumps. Prominent grass species include *Poa fendleriana* and *Koeleria pyramidata (K. cristata)*, with *Poa fendleriana* occurring most consistently. These two species are considered relatively better adapted to mesic conditions compared to grasses of drier *Pinus ponderosa* habitat types. *Artemisia* spp. are usually present, *A. ludoviciana* being common; *Erigeron* spp. and *Lithospermum multiflorum* also are common forbs.

Physical features.—The PIPO/QUGA HT is generally found on canyon side slopes or upper ridges of northwest, north, and northeast exposures at elevations near 7,000 feet (2,135 m). Patches of exposed mineral soil often can be found in open areas, along with evidence of surface runoff. Also, accumulation of oak and conifer litter may be high under a closed canopy.

Ecotones and adjacent habitats.—At the lower elevational limits of this habitat type, transition to either the drier *Pinus ponderosa/Quercus undulata* habitat type or to pinyon-juniper woodlands occurs. Transitions at upper elevations are usually to the more mesic PSME/QUGA or ABCO/QUGA habitat types.

Discussion.—This habitat type does not appear to be extensive on the Lincoln National Forest. It may, however, be more widely distributed on the Mescalero Apache Indian Reservation, since larger geographical areas lie within the normal elevational range of the habitat type.

The PIPO/QUGA HT is, perhaps, under-sampled in this study, primarily because of disturbance that was particularly evident near Ruidoso, N. Mex. Logging, which was extensive in this area, commonly removed all mature trees and left young stands with few clues as to the climax conditions. Consequently, successional studies are needed to establish the extent of forest covered by this habitat type, which is similar to seral stages of the PSME/QUGA HT.

Figure 11.—*Pinus ponderosa/Quercus gambelii* habitat type. Plot 830, Windy Canyon, Lincoln National Forest (6,920 feet or 2,110 m). *Pinus ponderosa* dominant; no mixed conifer species; *Quercus gambelii* abundant.

Pinus ponderosa/Quercus undulata habitat type (PIPO/QUUN; ponderosa pine/wavyleaf oak)

Vegetation.—*Pinus ponderosa* is the climax dominant tree species in the three phases of this habitat type (fig. 12). *Pinus edulis* and *Juniperus deppeana* are minor climax species, and are more abundant in the Quercus undulata phase than the other two phases.

Figure 12.—*Pinus ponderosa/Quercus undulata* habitat type. Plot 817, Upper Carr Canyon, Lincoln National Forest (6,960 feet or 2,120 m). *Pinus ponderosa* dominates canopy, with *Juniperus deppeana* and *Pinus edulis* present. *Quercus undulata* very abundant, over 5% of site covered.

Quercus undulata is the diagnostic undergrowth species for the habitat type, being most abundant in the QUUN phase and decreasing to 5% coverage in the others. It readily hybridizes with other species of oak, especially *Quercus gambelii* and *Q. grisea*, making identification difficult. Generally, characteristics of *Quercus undulata* are evident in all oak species in this habitat type.

Muhlenbergia dubia is a consistent component of the grassy vegetation comprising this habitat type. Other grass species commonly found in all phases of the habitat type include *Aristida arizonica*, *Bouteloua curtipendula*, *Lycurus phleoides*, and *Schizachyrium scoparium* (*Andropogon scoparius*). The forb layer is not well developed: however, *Artemisia ludoviciana*, *Erigeron divergens*, and *Lithospermum multiflorum* are common.

***Quercus undulata* (QUUN) typic phase.**—This typic phase of the habitat type can be distinguished by the high oak coverage, ranging between 5% and 15%. *Muhlenbergia dubia* and *M. emersleyi* each have a coverage of about 1%.

***Muhlenbergia dubia* (MUDU) phase.**—The diagnostic species identifying this grassy phase is *Muhlenbergia dubia*, covering 3% to 8% of the ground surface. *Muhlenbergia emersleyi* also is found in this phase, often as abundant as *M. dubia*.

Lower coverage values for *Quercus undulata* (less than 5%) and resultant higher coverage values for *M. dubia* (greater than 1%) help to distinguish this phase from the QUUN phase.

***Muhlenbergia longiligula* (MULO) phase.**—This phase is characterized by the dominance of *M. longiligula*, although *M. dubia* will occasionally be present. *Piptochaetium fimbriatum* and *Bouteloua gracilis* also are abundant components of this phase.

Physical features.—The PIPO/QUUN HT occupies nearly all topographical situations and all aspects, most commonly south to southeasterly. It is found between 6,500 and 8,000 feet (1,980 and 2,440 m). As in the PIPO/QUGA HT, exposed mineral soil and evidence of surface runoff can be observed, but usually there is a well-developed litter layer from high coverage of oaks and grasses.

Ecotones and adjacent habitats.—The PIPO/QUUN HT is the driest habitat type of the *Pinus ponderosa* series. The QUUN phase of this habitat type borders pinyon-juniper woodlands. The MUDU phase of the habitat type adjoins either the QUUN phase or gradates directly into pinyon-juniper types on the Lincoln National Forest (Kennedy 1983). Within the Sacramento Mountains, the spatial transition from the MUDU phase into the QUUN phase can be gradual as *Quercus undulata* slowly increases in abundance. The MULO phase of this habitat type tends to be found in islands within areas covered by the MUDU phase. The upper elevational limits of the PIPO/QUUN HT are bordered by either the PIPO/QUGA HT or the PSME/QUGA HT, depending on the abruptness of the transition to wetter, cooler conditions.

Discussion.—The PIPO/QUUN HT, while not extensive, is distributed throughout the Lincoln National Forest. It is, however, restricted to rather narrow elevational belts lying between the pinyon-juniper and mixed conifer forests. Historically, fire probably was an important element in the successional development of this habitat type, observational evidence suggesting that such fires burned with high intensities but low frequencies.

Of interest is the diversity of this type on the eastern flank of Capitan Peak. Chinquapin oak, *Quercus muehlenbergii*, may appear on canyon soils where this type occurs. On canyon sideslopes, much more pinyon-juniper is found mixed with *Pinus ponderosa*.

SUMMARY AND CONCLUSIONS

There are 13 forest habitat types on the Lincoln National Forest. Types range from the cold *Picea engelmannii* series through the warm *Pinus ponderosa* series. This study partitioned forest diversity into recognizable taxonomic units. The ultimate objective of providing land managers with predictive capabilities can be realized only by refinement of the classification and by correlating management implications with habitat types. The refining process may be accomplished best by successional studies, which will identify the seral stages in the ecosystem preceding the climax stage. Similarly, synthesis of existing information and additional research are needed to more fully understand the response of habitat types to natural and human-related activities.

The *Picea engelmannii* and *Abies lasiocarpa* series are found at high elevations in the Sacramento Mountains, White Mountains, and Capitan Mountains. These series represent the coldest and snowiest forested types of the southwestern United States. However, the description of these high-elevation spruce-fir habitat types differs from related types in the northern parts of the Rocky Mountains (Daubenmire 1943, 1952; Oosting and Reed 1952; Ellison 1954; Langenheim 1962; Pfister et al. 1977; Steele et al. 1981). These differences probably result from the combined effect of isolation and lack of genetic exchange between forests of southern New Mexico and other areas.

The *Picea pungens* series is a very restricted group of habitat types, and is not an extensive timber producer in the Southwest or on the Lincoln National Forest in particular. Habitat types of this series are indicative of cool, moist canyons at mid-elevations. These attractive sites have historically been exploited, and few stands remain that exhibit even remnants of pristine conditions.

The most extensive series on the Lincoln National Forest is *Abies concolor*, which exhibits a great diversity of habitat types because of its wide amplitude. Timber species within the series include the lower valued *Abies* and other softwoods of higher value—*Pseudotsuga menziesii*, *Pinus strobiformis*, and *P. ponderosa*. Site conditions in the series range from mesic habitat types where dominance by *Abies* is expressed in early successional

stages, to the drier types in which the more valuable species dominate the seral stages, although *Abies* ultimately occupies the climax position.

An interesting question is posed by the *Pseudotsuga menziesii* series: Is it a climatic climax, an edaphic climax, or are pure stands of *P. menziesii* a result of a lack of an *Abies concolor* seed source? Furthermore, *Pseudotsuga* stands must be critically evaluated to determine if the type is maintained by disturbance to the exclusion of *Abies*, or if it is truly a response to climatic or edaphic conditions. The lack of a seed source apparently can be ruled out because, in this study, stands lacking *A. concolor* were found adjacent to *P. menziesii* stands in which *A. concolor* reproduction was abundant. While no disturbance was observed in these *P. menziesii* stands to account for the absence of *A. concolor*, sites probably exist where disturbance is the contributing factor. Disturbance most often is caused by low-intensity fires and biotic agents such as mistletoe which, by opening the canopy, expose the site to the inhibiting effects of intense solar radiation on the establishment of shade-tolerant species such as *A. concolor* (Ronco 1970, Jones 1974).

The *Pinus ponderosa* series on the Lincoln National Forest has high commercial value, but it is relatively small in size, occupying the area between pinyon-juniper woodlands and mixed conifer forests. Quite often it is absent or occupies a narrow transition zone between the two cover types. Prior to exclusion of low-intensity fires, disclimax *P. ponderosa* types extended into the ecotones of other forest series at lower and higher elevations. Stands in the *P. ponderosa* series often were highly disturbed from catastrophic fires as a result of increased fuels accumulated since fire control measures were initiated. Consequently, locating stands in which to sample was difficult in the present study. Grazing also has commonly contributed to the general disturbance in this series, particularly in the Sacramento Mountains where it has completely altered the species composition in many instances. Because of such widespread disturbance, use of this classification and appropriate keys may be difficult.

Disturbance has had, and probably will continue to have, a major ecological impact on the Lincoln National Forest. Prior to European settlement, fire was the major disturbance, and as a natural part of the ecosystem, exerted adaptive pressures on species inhabiting the ecosystem. This adaptability is most evident in *Pinus ponderosa* forests. In sampling these forests during this study, it became apparent that pure, or nearly pure, stands of *P. ponderosa* once occupied a larger area than they do today, as evidenced by the mature overstory of *P. ponderosa* being replaced by more tolerant mixed conifer species such as *Pseudotsuga menziesii* and *Abies concolor*. Given the assumption that *Pinus ponderosa* is less susceptible to fire than some of the other mixed conifer species, the conclusion can be drawn that these stands were once a *P. ponderosa* disclimax. In order to address these obvious successional changes, land managers must be aware of their existence and adopt fire management policies and silvicultural systems to favor—depending on management objectives—one or more species having different degrees of fire and shade tolerances.

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APPENDIXES

Appendix A. Keys to the Climax Forest Series and Habitat Types of the Lincoln National Forest

Keys for series and habitat types on the Lincoln National Forest are presented in this section., The first step in using keys in habitat type classification is to determine the series level of a particular site through identification of climax overstory tree species. A climax species is well represented in the overstory of mature stands, and also is reproducing in the understory. In contrast, younger stands will have reproduction of the climax species under the canopy, even though older individuals of the species may not be present in the overstory. Field investigators must judge whether such reproduction will grow to maturity to become the climax dominant when the stand matures. This determination becomes more difficult the younger the stand, especially in the *Abies concolor* series. Similarly, the *Pinus ponderosa* series also will present problems in that reproduciton may be sparse on drier sites, forcing investigators to search carefully for *P. ponderosa* reproduction in the ponderosa pine/pinyon-juniper ecotone.

Furthermore, diagnostic species may not always be present in a particular stand because of the lack of a seed source or disturbance. In such instances, the investigator must compare the site in question to written descriptions in order to correctly identify the habitat type. Similarly, when choices in the keys are not clear because of site conditions, written descriptions and synoptic tables should be used to distinguish between types.

A1. Key to Climax Forest Series

1. PIEN or ABLA present in overstory, or regeneration sufficient to confirm their status as climax dominants; PIPU rare, usually absent ———— 2
1. PIEN and ABLA absent, or if present, then PIPU also prominent ———— 3
   2. ABLA present in overstory and/or as reproduction ———— ABLA series
   2. ABLA absent or accidental ———— PIEN series
3. PIPU present in overstory and/or as reproduction ———— PIPU series
3. PIPU absent; ABCO, PSME, or PIPO present ———— 4
   4. ABCO present in overstory, or prominent in understory. ABCO not accidental, truly climax. Other species present but not as climax dominants ———— ABCO series
   4. ABCO absent or accidental, not a dominant component of the overstory or understory ———— 5
5. PSME clearly the dominant climax species; PIPO late successional; ABCO absent or accidental ———— PSME series
5. PSME not a strong element of either overstory or understory. PIPO the climax dominant – PIPO series

A2. Key to *Picea engelmannii, Abies lasiocarpa*, and *Picea pungens* Series Habitat Types

1. PIPU present in overstory and/or as reproduction ———— PIPU/FROV HT
1. PIPU absent or accidental ———— 2
   2. ABLA present in overstory and/or as reproduction ———— ABLA/SESA HT
   2. ABLA absent or accidental ———— 3
3. Low elevation forests, Sacramento Mountains; *Acer glabrum* present ———— PIEN/ACGL HT
3. High elevation forests, Capitan Peak; *Elymus triticoides* present ———— PIEN/ELTR HT

A3. Key to *Abies concolor* Series Habitat Types

1. *Acer grandidentatum* present and dominant in association with *A. glabrum* ———— ABCO/ACGR HT
   1a. *Holodiscus dumosus* absent ———— ACGR typic phase
   1b. *Holodiscus dumosus* present ———— HODU phase
1. *Acer grandidentatum* absent, or not dominant in association with *A. glabrum* ———— 2
   2. Capitan Mountain sites, *Elymus triticoides* abundant ———— ABCO/ELTR HT
   2. Other locations, *Elymus triticoides* rare ———— 3
3. *Acer glabrum* substantial shrub component, *Pinus ponderosa* absent or accidental ———— ABCO/ACGL HT
   3a. *Holodiscus dumosus* present — HODU phase
3. *Acer glabrum* absent; *Holodiscus dumosus* may be present, but not associated with *A. glabrum; Pinus ponderosa* common ———— 4
   4. Riparian sites. *Juglans major* present, *Populus angustifolia* sometimes present ———— ABCO/JUMA HT
   4. Non-riparian sites. *Juglans major* and *Populus angustifolia* absent ———— 5
5. Understory extremely sparse over wide areas (not isolated pockets). Virtually no shrub representation; grass cover under 2%, diversity extremely low ———— ABCO/Sparse HT
5. Understory well represented. Shrubs a definite component; *Quercus gambelii* prominent (5% or greater coverage); grasses well represented ———— ABCO/QUGA HT
   5a. *Holodiscus dumosus, Festuca arizonica, Muhlenbergia virescens*, and *M. dubia* absent ———— QUGA typic phase
   5b. *Holodiscus dumosus* present — HODU phase
   5c. *Festuca arizonica* dominant —— FEAR phase
   5d. *Muhlenbergia virescens* dominant ———— MUVI phase
   5e. *Muhlenbergia dubia* dominant ———— MUDU phase

A4. Key to *Pseudotsuga menziesii* Habitat Types

1. *Quercus gambelii* the dominant tall shrub ———— PSME/QUGA HT
   - 1a. *Holodiscus dumosus* absent; grass diversity high ———— QUGA typic phase
   - 1b. *Holodiscus dumosus* present; grass diversity low, *Bromus richardsonii* common ———— HODU phase

A5. Key to *Pinus ponderosa* Habitat Types

1. *Quercus gambelii* the prominent oak, no evidence of hybridization with *Q. undulata.* —— PIPO/QUGA HT
1. *Quercus gambelii* not the prominent oak, absent or clearly hybridizes with *Quercus undulata*, the dominant oak ———— PIPO/QUUN HT
   - 1a. *Quercus undulata* greater than 5% cover. *Muhlenbergia dubia* usually less than 5% cover ———— QUUN typic phase
   - 1b. *Quercus undulata* with less than 5% cover. *Muhlenbergia dubia* with higher coverages ———— MUDU phase
   - 1c. *Muhlenbergia longiligula* present ———— MULO phase

Appendix B. Plant List of All Species Identified in Study[1]

Trees

Abies concolor
Abies lasiocarpa
Acer negundo
Fraxinus pennsylvanica
Juglans major
Juniperus deppeana
Juniperus monosperma
Juniperus osteosperma
Juniperus scopulorum
Picea pungens
Picea engelmannii
Pinus edulis
Pinus ponderosa
Pinus strobiformis
Populus angustifolia
Populus tremuloides
Pseudotsuga menziesii

Shrubs

Acer glabrum
Acer grandidentatum
Berberis fremontii
Berberis repens
Ceanothus fendleri
Cercocarpus montanus
Cornus stolonifera
Fallugia paradoxa
Fendlera rupicola
Gutierrezia sarothrae
Holodiscus dumosus
Jamesia americana
Lonicera involucrata
Parthenocissus inserta
Physocarpus monogynus
Prunus virginiana
Ptelea trifoliata
(P. angustifolia)
Quercus gambelii
Quercus grisea
Quercus muehlenbergii
Quercus undulata
Quercus X (hybrid)
Rhamnus betulaefolia

Shrubs—continued

Rhamnus californica
Rhus radicans
Rhus trilobata
Ribes spp.
Ribes cereum
Ribes inerme
Ribes montigenum
Ribes pinetorum
Ribes wolfii
Robinia neomexicana
Rosa spp.
Rosa arizonica
Rubus parviflorus
Rubus strigosus
Salix scouleriana
Sambucus glauca
Sambucus microbotrys
Symphoricarpos oreophilus
Vitis arizonica
Yucca angustissima
Yucca baccata

Graminoids

Agropyron trachycaulum
Andropogon gerardi
Andropogon pseudorepens
Aristida arizonica
Blepharoneuron tricholepis
Bouteloua curtipendula
Bouteloua gracilis
Bromus spp.
Bromus marginatus
Bromus richardsonii
Carex spp.
Carex foenea
Carex occidentalis
Carex rossii
Carex siccata
Cyperus fendlerianus
Dactylis glomerata

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[1] *Nomenclature and authority (not shown) follow that of Lehr (1978).*

Appendix B—continued

Graminoids—continued

Elymus ambiguus
Elymus glaucus
Elymus triticoides
Festuca arizonica
Festuca sororia
Festuca thurberi
Juncus balticus
Koeleria pyramidata
(K. cristata)
Luzula parviflora
Lycurus phleoides
Melica porteri
Muhlenbergia dubia
Muhlenbergia emersleyi
Muhlenbergia longiligula
Muhlenbergia montana
Muhlenbergia pauciflora
Muhlenbergia virescens
Panicum bulbosum
Piptochaetium fimbriatum
Poa annua
Poa fendleriana
Poa interior
Poa leptocoma
Poa occidentalis
Poa palustris
Poa pratensis
Schizachyrium cirratum
Schizachyrium scoparium
(Andropogon scoparius)
Sitanion hystrix
Stipa spp.
Stipa columbiana
Stipa lettermanii
Stipa pringlei
Trisetum montanum

Forbs

Achillea millefolium
(A. lanulosa)
Actaea arguta
Agoseris glauca
Allium spp.
Allium cernuum
Androsace occidentalis
Antennaria parvifolia
Aquilegia elegantula
Arabis fendleri
Arenaria spp.
Arenaria lanuginosa
Artemisia carruthii
Artemisia dracunculus
Artemisia frigida
Artemisia ludoviciana
Astragalas spp.
Astragalus rusbyi

Forbs—continued

Bahia dissecta
Bidens bipinnata
Brickellia californica
Brickellia grandiflora
Calliandra humilis
Campanula rotundifolia
Castilleja spp.
Chaptalia alsophila
Chenopodium album
Chimaphila umbellata
Cirsium parryi
Clematis ligusticifolia
Clematis pseudoalpina
Commelina dianthifolia
Corallorhiza maculata
Corallorhiza wisteriana
Cystopteris fragilis
Delphinium spp.
Draba aurea
Draba helleriana
Dugaldia hoopesii
(Helenium hoopesii)
Epilobium angustifolium
Erigeron divergens
Erigeron flagellaris
Erigeron macranthus
Erigeron platyphyllus
Erigeron superbus
Eriogonum spp.
Eriogonum jamesii
Erodium cicutarium
Erysimum capitatum
Eupatorium herbaceum
Euphorbia fendleri
Euphorbia lurida
Euphorbia palmeri
Fragaria bracteata
Fragaria ovalis
Galium spp.
Galium asperrimum
Galium boreale
Galium microphyllum
Galium triflorum
Galium wrightii
Geranium caespitosum
Geranium richardsonii
Goodyera oblongifolia
Habenaria sparsiflora
Haplopappus parryi
Hedeoma drummondii
Hedeoma oblongifolium
Heterotheca fulcrata
Heuchera parvifolia
Hieracium fendleri
Hymenoxys richardsonii
Ipomopsis aggregata
Iris missouriensis

Forbs—continued

Lappula redowskii
Lathyrus arizonicus
Lathyrus eucosmus
Lathyrus leucanthus
Lesquerella gordoni
Ligusticum porteri
Lithospermum multiflorum
Lonicera spp.
Lonicera arizonica
Lonicera utahensis
Lupinus spp.
Lupinus argenteus
Lupinus kingii
Malaxis soulei
Melilotus officinalis
Mirabilis oxybaphoides
Monotropa hypopitys
Myosotis scorpioides
Oenothera hookeri
Opuntia spp.
Orobanche cooperi
Orobanche multiflora
Osmorhiza chilensis
Osmorhiza depauperata
Oxalis alpina
Oxytropis lambertii
Pachystima myrsinites
Pellaea atropurpurea
Penstemon spp.
Penstemon virgatus
Phacelia magellanica
Phlox spp.
Phlox nana
Polygala alba
Polygonum spp.
Potentilla spp.
Potentilla crinita
Potentilla thurberi
Polemonium delicatum
Polemonium foliosissimum
Pseudocymopterus montanus
Psoralea tenuiflora
Pteridium aquilinum
Pyrola secunda
Ranunculus inamoenus
Rudbeckia laciniata
Senecio spp.
Senecio actinella
Senecio arizonicus
Senecio bigelovii
Senecio cardamine
Senecio eremophilus
Senecio hartianus
Senecio lemmoni
Senecio multilobatus
Senecio neomexicanus
Senecio sacramentanus
Senecio sanguisorboides
Senecio spartioides
Senecio wootonii
Silene laciniata
Silene scouleri
Sisymbrium spp.
Sisymbrium altissimum
Smilacina racemosa
Smilacina stellata
Solidago spp.
Stellaria jamesiana
Stellaria longifolia
Swertia radiata
Taraxacum laevigatum
Taraxacum officinale
Thalictrum fendleri
Thermopsis pinetorum
Thlaspi montanum
Townsendia exscapa
Trifolium dubium
Urtica serra
Valeriana spp.
Valeriana capitata
Valeriana edulis
Verbascum thapsus
Vicia spp.
Vicia americana
Vicia pulchella
Viola spp.
Viola canadensis

Appendix C. Successional Status of Major Tree Species Within Habitat Types
C = major climax species S = major seral species a = accidental
c = minor climax species s = minor seral species

		Species										
Habitat type	**Phase**	**ABLA**	**PIEN**	**PIPU**	**POTR**	**ABCO**	**PSME**	**PIST**	**PIPO**	**QUGA**	**PIED**	**JUDE**
ABLA/SESA[1]		C	C	.	S	.	s	.	.	.	.	.
PIEN/ACGL[1]		c	C	.	S	.	c	.	.	.	.	.
PIEN/ELTR[1]		c	C	.	S	a	c	.	.	.	.	.
PIPU/FROV		.	c	C	s	c	C	S	S	.	.	.
ABCO/ACGR	ACGR typic[1]	.	.	.	.	C	c	c	a	s	.	.
	HODU	.	.	.	.	C	c	c	a	s	.	.
ABCO/ELTR[1]		.	a	.	.	C	c	c	a	c	.	.
ABCO/ACGL[1]	HODU	.	.	.	.	C	C	s	a	s	.	.
ABCO/QUGA	QUGA typic[1]	.	.	.	.	C	C	S	S	S	a	.
	HODU[1]	.	.	.	.	C	C	c	s	S	.	.
	FEAR[1]	.	.	.	.	C	C	c	c	S	.	.
	MUVI[1]	.	.	.	.	C	C	c	S	S	a	.
	MUDU	.	.	.	.	C	C	c	s	S	a	a
ABCO/Sparse[1]		.	.	.	s	C	C	S	S	.	.	.
ABCO/JUMA		.	.	.	s	C	S	a	S	s	a	a
PSME/QUGA	QUGA typic	.	.	.	.	.	C	c	S	S	s	s
	HODU	.	.	.	.	.	C	c	S	S	s	a
PIPO/QUGA		.	.	.	.	.	.	.	C	S	c	s
PIPO/QUUN	QUUN typic	.	.	.	.	.	.	.	C	s	c	c
	MUDU	.	.	.	.	.	.	.	C	s	c	c
	MULO	.	.	.	.	.	.	.	C	s	c	c

[1]*From Moir and Ludwig (1979).*

Appendix D. Average Density and Constancy

Species and Size class	ABLA/SESA HT (N = 9)	PIEN/ACGL HT (N = 2)	PIEN/ELTR HT (N = 4)	PIPU/FROV HT (N = 5)	ABCO/QUGA HT QUGA typic P (N = 18)	HODU P (N = 7)	FEAR P (N = 4)	MUVI P (N = 1)	MUDU P (N = 2)
Abies lasiocarpa									
Yng regen	99/100	.	3/25	.	.	.	.	.	.
Adv regen	13/100	.	6/50	.	.	.	.	.	.
Mature	12/100	.	1/50	.	.	.	.	.	.
Picea engelmannii									
Yng regen	24/89	16/100	35/100	2/20	.	.	.	.	.
Adv regen	9/89	21/100	16/100	2/40	.	.	.	.	.
Mature	4/67	10/100	6/100	2/40	.	.	.	.	.
Picea pungens									
Yng regen	.	.	.	3/60	.	.	.	.	.
Adv regen	.	.	.	3/80	.	.	.	.	.
Mature	.	.	.	4/100	.	.	.	.	.
Populus tremuloides									
Yng regen	.	.	3/25	.	.	7/14	.	.	.
Adv regen	.	.	1/25	.	3/11	1/14	.	.	.
Mature	7/50	1/11	2/50	2/40	.	.	.	.	.
Abies concolor									
Yng regen	.	.	.	9/80	15/83	14/100	6/50	11/100	3/100
Adv regen	.	1/50	.	4/80	8/88	11/100	1/50	13/100	6/100
Mature	.	1/50	.	2/80	3/83	4/86	.	.	1/50
Pseudotsuga menziesii									
Yng regen	.	.	3/50	7/60	19/100	25/100	22/50	8/100	17/100
Adv regen	.	5/100	1/25	11/80	10/88	7/100	3/75	10/100	13/100
Mature	1/22	3/100	9/100	2/100	4/77	1/29	1/50	.	2/50
Pinus strobiformis									
Yng regen	.	1/50	4/25	3/20	6/72	13/100	15/100	11/100	9/50
Adv regen	.	.	2/50	3/60	10/50	8/86	10/100	6/100	8/50
Mature	.	.	2/50	.	3/27	1/29	1/25	.	4/50
Pinus ponderosa									
Yng regen	.	.	.	1/20	5/38	1/43	5/75	8/100	4/100
Adv regen	.	.	.	.	8/55	1/29	3/75	39/100	8/100
Mature	.	.	.	1/20	4/61	1/29	5/75	7/100	7/50
Pinus edulis									
Yng regen	.	.	.	.	2/27	1/14	.	.	.
Adv regen	.	.	.	.	.	.	.	.	.
Mature	.	.	.	.	.	.	.	.	.
Juniperus deppeana									
Yng regen	.	.	.	.	1/22	.	.	.	.
Adv regen	.	.	.	.	2/5	.	.	.	.
Mature	.	.	.	.	.	.	.	.	.

[1]Occurrence of each species in each habitat type and phase is indicated by two values separated by a slash. The first indicates the mean density (in percent) per plot for the tree species. In all cases, however, the first value is the mean for only the plots in which the species was present. The value to the right of the slash is the constancy for each species in the habitat type or phase; it is the percentage of the total number of plots in the group in which the species was found. A dot indicates that the species was not found in a group.

of Tree Species by Habitat Type and Phase[1]

ABCO/ACGR HT		ABCO/ELTR	ABCO/ACGL	ABCO/Sparse	ABCO/JUMA	PSME/QUGA HT		PIPO/QUGA	PIPO/QUUN HT		
ACGR typic P (N=3)	HODU P (N=3)	HT (N=4)	HT, HODU P (N=17)	HT (N=1)	HT (N=4)	QUGA typic P (N=9)	HODU P (N=6)	HT (N=2)	QUUN typic P (N=7)	MUDU P (N=8)	MULO P (N=2)
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	6/1	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
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.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	2/23	.	.	.	.	.	.	.	.
.	1/33	3/50	4/29	.	.	.	.	.	.	.	.
.	1/33	.	1/6	.	.	.	.	.	.	.	.
9/100	46/100	21/100	12/76	100/100	12/75	.	1/17	.	1/14	.	.
14/100	9/100	5/100	10/100	17/100	4/75	.	.	.	1/14	1/25	.
1/67	2/67	2/75	7/88	4/100	5/75	.	.	.	.	1/13	.
6/100	7/100	25/100	7/94	17/100	1/25	24/100	15/100	.	1/57	3/38	.
6/67	4/100	5/100	5/82	2/100	.	8/100	15/100	.	2/57	2/50	.
.	3/100	3/75	4/76	8/100	1/25	3/89	2/83	.	1/29	1/13	.
5/100	2/67	6/75	2/65	13/100	.	11/89	16/100	.	.	2/13	.
1/67	1/33	8/75	1/47	8/100	.	6/89	9/100	.	.	1/13	.
1/33	2/67	1/25	1/24	.	.	1/44	3/83	.	.	1/13	.
5/100	.	1/25	1/6	.	9/50	5/67	1/17	2/100	12/86	19/100	2/50
7/67	.	.	.	.	4/75	10/89	3/67	12/50	9/100	28/100	24/100
2/67	.	.	.	.	1/50	2/67	1/50	2/50	5/100	1/50	6/100
2/33	.	.	.	.	8/50	19/67	3/50	28/100	18/86	11/100	7/100
1/33	.	.	.	.	.	1/33	.	10/100	4/86	4/63	3/50
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	3/50	1/33	1/17	2/50	6/86	24/100	7/100
.	.	.	.	.	1/50	.	1/17	2/50	5/86	7/100	7/100
1/33	.	.	.	.	1/25	1/11	.	.	1/57	1/63	.

Appendix E. Average Cover and Constancy of Major Shrub

Species and Size class	ABLA/SESA HT (N = 9)	PIEN/ACGL HT (N = 2)	PIEN/ELTR HT (N = 4)	PIPU/FROV HT (N = 5)	ABCO/QUGA HT: QUGA typic P (N = 18)	ABCO/QUGA HT: HODU P (N = 7)	ABCO/QUGA HT: FEAR P (N = 4)	ABCO/QUGA HT: MUVI P (N = 1)	ABCO/QUGA HT: MUDU P (N = 2)
Shrubs									
Acer glabrum	T/33	T/50	2/50	20/60	T/5	.	.	.	.
Acer grandidentatum	.	.	.	.	T/5	1/29	.	.	.
Cercocarpus montanus	.	.	.	.	1/28	.	T/50	.	.
Holodiscus dumosus	.	T/100	5/75	6/80	4/33	12/100	.	.	.
Jamesia americana	.	T/50	3/75	.	.	T/14	.	.	.
Pachystima myrsinites	.	4/50	.	.	.	.	.	.	.
Physocarpus monogynus	.	.	.	.	7/5	.	T/25	.	.
Prunus virginiana	.	.	.	T/20	3/5	T/29	.	.	.
Quercus gambelii	.	T/50	.	1/80	17/100	13/100	26/100	20/100	11/100
Quercus grisea	.	.	.	.	.	.	.	.	.
Quercus undulata	.	.	.	.	T/5	.	.	.	.
Ribes spp.	3/100	.	3/50	1/60	7/39	T/28	T/25	.	T/50
Robinia neomexicana	.	T/50	.	.	T/44	T/43	T/75	.	.
Rosa spp.	.	.	.	T/40	T/28	T/29	T/75	.	.
Symphoricarpos oreophilus	.	.	.	T/20	T/39	1/86	T/25	.	.
Vitis arizonica	.	.	.	.	.	.	.	.	.
Graminoids									
Andropogon gerardi	.	.	.	.	.	.	.	.	.
Aristida arizonica	.	.	.	.	.	.	.	.	.
Blepharoneuron tricholepsis	.	.	.	.	.	.	T/25	.	.
Bouteloua gracilis	.	.	.	.	.	.	.	.	.
Bromus richardsonii	1/100	2/100	T/25	1/100	2/89	3/86	T/50	.	1/50
Carex spp.	.	.	.	T/40	T/5	T/14	.	2/100	3/50
Carex foenea	T/22	.	.	.	.	.	.	.	.
Carex rossii	.	.	T/75	.	T/28	.	2/100	.	.
Elymus triticoides	.	.	20/50	.	2/11	.	.	.	.
Festuca arizonica	.	.	.	.	T/33	.	6/75	T/100	.
Koeleria pyramidata	.	.	.	.	T/39	T/14	T/50	.	.
Muhlenbergia dubia	.	.	.	.	.	.	.	.	1/100
Muhlenbergia emersleyi	.	.	.	.	.	.	.	.	.
Muhlenbergia longiligula	.	.	.	.	6/5	.	.	.	.
Muhlenbergia montana	.	.	.	.	1/17	.	1/75	.	.
Muhlenbergia virescens	.	.	.	.	T/11	.	.	T/100	.
Piptochaetium fimbriatum	.	.	.	.	.	.	.	.	.
Poa fendleriana	.	.	.	1/40	1/67	T/14	2/75	.	T/50
Poa pratensis	.	.	.	30/60	T/5	T/14	.	.	.
Schizachyrium scoparium	.	.	.	.	.	.	.	.	.
Sitanion hystrix	.	.	.	.	T/44	.	T/50	.	T/50
Stipa spp.	.	.	.	.	T/11	.	1/25	.	2/50
Stipa pringlei	.	.	.	.	.	.	.	10/100	.
Trisetum montanum	2/100	T/100	T/75	3/80	.	T/29	.	.	.
Forbs									
Achillea millefolium	.	.	.	1/60	T/22	2/14	T/25	.	.
Antennaria parvifolia	.	.	.	.	.	.	.	.	.
Aquilegia elegantula	.	.	.	1/60	.	T/43	.	.	.
Artemisia frigida	T/56	2/100	T/25	.	1/11	T/14	.	.	.
Artemisia ludoviciana	.	.	.	.	T/44	.	T/75	.	.
Brickellia grandiflora	.	.	.	.	T/17	T/71	.	.	3/50
Campanula rotundifolia	.	.	.	.	T/5	.	.	.	.
Chaptalia alsophila	.	.	.	.	T/5	T/43	.	.	.
Clematis pseudoalpina	.	.	.	.	1/11	T/43	.	.	.
Clematis ligusticifolia	.	.	.	.	.	T/71	.	.	.
Cystopteris fragilis	.	.	.	2/80	T/5	T/29	.	.	.
Dugaldia hoopesii	.	.	.	.	.	.	.	.	.
Erigeron spp.	.	.	T/25	5/20	T/5	T/29	.	.	.
Erigeron macranthus	.	.	.	T/40	1/22	.	.	.	.
Erigeron platyphyllus	.	.	.	.	1/28	.	T/25	.	.
Erigeron superbus	4/100	T/50	T/50	.	T/17	2/14	3/50	.	.
Eriogonum jamesii	.	.	.	.	T/22	.	.	.	.
Fragaria bracteata	.	T/50	T/75	1/80	T/33	T/43	.	.	.
Fragaria ovalis	T/33	T/100	.	.	T/5	T/29	.	.	.

[1] *Occurrence of each species in each habitat type and phase is indicated by two values separated by a slash. The first indicates the mean coverage (in percent) per plot for the shrubs, grasses, and forbs. In all cases, however, the first value is the mean for only the plots in which the species was present. The value to the right of the slash is the constancy for each species in the habitat type or phase; it is the percentage of the total number of plots in the group in which the species was found. In cases where a species had less than 1% cover, T is used to the left of the slash. A dot indicates that the species was not found in a group.*

and Herbaceous Species by Habitat Type and Phase[1]

ABCO/ACGR HT		ABCO/ELTR	ABCO/ACGL	ABCO/Sparse	ABCO/JUMA	PSME/QUGA HT		PIPO/QUGA	PIPO/QUUN HT		
ACGR typic P (N = 3)	HODU P (N = 3)	HT (N = 4)	HT, HODU P (N = 17)	HT (N = 1)	HT (N = 4)	QUGA typic P (N = 9)	HODU P (N = 6)	HT (N = 2)	QUUN typic P (N = 7)	MUDU P (N = 8)	MULO P (N = 2)
.	.	.	11/94	.	.	.	1/17	.	.	.	.
4/100	22/100	.	T/18	.	T/25	.	.	.	.	.	.
.	.	.	.	.	T/50	T/33	T/17	T/50	T/14	T/25	.
.	7/100	T/100	13/94	5/100	.	.	3/100	.	.	.	.
.	.	8/75	5/47	.	.	.	.	.	.	.	.
.	T/33	.	T/24	.	.	.	T/17	.	.	.	.
.	T/33	.	1/29	T/100	.	.	T/17	.	.	.	.
.	2/67	.	1/41	.	T/50	T/11	T/17	.	7/14	.	.
1/100	3/100	T/100	4/82	T/100	15/75	14/100	21/100	10/100	1/29	T/13	.
.	.	.	.	.	.	.	1/16	.	5/43	T/13	.
.	.	.	.	.	.	2/22	.	.	11/57	2/75	13/100
.	5/33	1/75	1/70	.	.	.	.	.	.	.	.
T/33	T/67	.	T/47	.	T/50	T/33	T/83	.	.	.	.
.	.	.	T/6	.	T/25	T/22	T/17	.	.	.	.
T/33	1/33	.	T/53	.	.	T/22	T/33	.	.	.	.
T/33	.	.	.	.	2/100	.	.	.	.	.	.
.	.	.	.	.	.	T/22	.	.	.	1/63	.
.	.	.	.	.	.	.	.	.	T/14	T/38	T/50
.	.	.	.	.	.	.	.	.	.	.	T/50
.	.	.	.	.	.	1/11	.	T/50	T/43	T/13	3/100
1/33	3/100	5/100	7/100	.	T/25	T/67	2/100	.	.	T/13	.
T/100	.	.	T/12	.	.	1/22	.	1/100	T/29	T/13	.
.	.	15/25	2/18	.	.	.	.	.	.	.	.
.	.	1/75	T/12	.	.	T/11	.	.	.	.	.
.	.	29/100	.	.	.	.	.	.	.	.	.
.	.	T/25	.	T/100	.	.	.	.	.	.	.
.	.	1/50	T/6	.	.	T/33	.	2/100	T/29	T/38	.
.	.	.	.	.	.	T/11	.	.	5/71	5/100	1/50
.	.	.	.	.	.	.	.	.	T/14	3/63	.
.	.	.	.	.	.	1/11	.	.	.	.	15/100
.	.	4/100	.	.	.	1/11	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	T/14	2/88	27/100
T/33	.	T/25	1/6	.	T/50	T/67	T/33	1/100	2/71	.	.
.	.	T/25	T/18	.	3/25	.	T/17	.	T/14	.	.
.	.	.	.	.	.	.	.	T/50	T/57	2/75	.
.	.	T/50	.	.	2/25	.	.	2/100	1/43	T/38	T/100
.	.	.	.	.	.	T/22	.	T/50	T/14	.	.
T/33	.	.	.	.	.	1/33	T/67	.	1/14	T/13	.
.	.	T/25	T/29	T/100	.	.	.	.	.	.	.
.	.	T/25	T/29	.	.	T/22	.	T/100	T/29	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	T/33	.	1/59	.	.	.	T/17	.	.	.	.
.	.	.	1/53	.	.	.	.	.	.	.	.
.	.	.	.	.	.	T/33	T/17	T/100	T/86	T/13	.
T/100	T/33	.	T/18	.	T/50	T/56	T/33	1/50	.	.	.
T/33	.	.	.	.	.	.	.	.	.	.	.
.	.	.	T/12	.	.	T/44	T/50	.	.	.	.
T/33	T/33	T/25	T/59	.	.	.	T/17	.	.	.	.
.	T/33	.	T/12	.	.	.	T/33	.	.	.	.
T/67	T/67	.	T/41	.	.	T/11	T/67	.	.	.	.
.	.	.	T/18	.	.	.	.	.	.	.	.
T/33	.	.	T/12	.	.	.	.	.	.	.	.
T/33	1/33	.	T/6	.	T/25	T/56	T/17	.	T/14	.	.
.	.	.	.	.	T/25	T/22	T/17	2/100	T/14	.	T/100
.	.	T/50	T/6	.	.	T/22	T/17	.	.	.	.
T/33	.	.	.	.	.	.	.	.	.	.	.
.	T/67	T/50	T/71	T/100	.	T/11	T/33	.	.	.	T/100
.	.	.	T/6	.	T/25	T/22	T/33	.	.	.	.

Species and Size class	ABLA/SESA HT (N = 9)	PIEN/ACGL HT (N = 2)	PIEN/ELTR HT (N = 4)	PIPU/FROV HT (N = 5)	ABCO/QUGA HT				
					QUGA typic P (N = 18)	HODU P (N = 7)	FEAR P (N = 4)	MUVI P (N = 1)	MUDU P (N = 2)
Forbs (continued)									
Galium boreale	.	.	.	1/20	T/33	T/71	.	.	.
Geranium caespitosum	.	T/50	T/25	1/60	T/55	T/29	T/50	.	.
Geranium richardsonii	T/56	T/50	.	3/60	.	.	.	.	T/50
Heuchera parvifolia	.	.	.	T/20	T/5	T/28	.	.	.
Hieracium fendleri	.	.	.	.	T/5	.	.	.	.
Iris missouriensis	.	.	.	1/80	T/5	T/14	.	.	.
Lathyrus arizonicus	.	4/50	T/25	1/80	T/33	T/29	T/25	.	T/100
Ligusticum porteri	T/100	T/100	.	.	.	.	.	.	.
Lithospermum multiflorum	.	.	.	.	T/11	.	T/25	.	.
Osmorhiza depauperata	2/89	T/50	.	.	.	.	.	.	.
Oxalis alpina	.	.	.	5/20	T/5	T/14	.	.	.
Penstemon spp.	.	.	T/25	.	1/5	.	.	.	.
Pseudocymopterus montanus	2/67	T/100	.	1/80	T/22	T/57	.	.	.
Pyrola secunda	T/78	T/50	T/25	.	.	.	.	.	.
Senecio neomexicanus	.	.	.	.	T/11	.	.	.	.
Senecio sacramentanus	.	.	.	.	.	.	.	.	.
Senecio sanguisorboides	7/100	1/100	.	.	.	.	.	.	.
Senecio wootonii	.	.	.	.	T/11	T/14	T/50	.	.
Smilacina racemosa	.	T/100	.	.	T/5	T/14	.	.	.
Smilacina stellata	T/33	T/50	T/50	.	T/17	T/71	.	.	.
Stellaria jamesiana	.	1/50	.	.	T/11	T/43	.	.	.
Thalictrum fendleri	.	T/100	.	T/40	2/61	T/86	1/25	.	.
Valeriana spp.	.	.	.	2/20	.	1/28	.	.	.
Valeriana capitata	.	.	.	15/20	.	T/28	.	.	.
Vicia americana	.	.	T/50	.	T/17	T/14	.	.	.
Viola canadensis	T/78	T/100	T/25	.	.	.	.	.	.

and Herbaceous Species by Habitat Type and Phase[1]—continued

ABCO/ACGR HT		ABCO/ELTR	ABCO/ACGL	ABCO/Sparse	ABCO/JUMA	PSME/QUGA HT		PIPO/QUGA	PIPO/QUUN HT		
ACGR typic P (N = 3)	HODU P (N = 3)	HT (N = 4)	HT, HODU P (N = 17)	HT (N = 1)	HT (N = 4)	QUGA typic P (N = 9)	HODU P (N = 6)	HT (N = 2)	QUUN typic P (N = 7)	MUDU P (N = 8)	MULO P (N = 2)
T/100	T/67	.	T/41	.	T/25	T/67	T/67	T/50	.	.	.
.	.	T/75	T/35	.	T/50	T/67	T/83	T/100	T/29	T/13	.
T/33	.	.	3/6	.	.	T/22	T/33	.	.	.	.
T/67	T/33	.	1/6	T/100	.	.	.	.	.	.	.
.	.	.	.	.	.	T/44	.	.	.	T/13	.
.	.	T/25	1/18	.	.	.	.	.	.	.	.
T/67	.	T/50	T/29	.	T/25	T/67	T/67	T/100	.	.	T/50
.	.	.	T/12	.	.	.	.	.	.	.	.
T/33	.	.	T/6	.	T/25	T/33	.	T/100	T/71	T/25	T/50
T/33	T/33	.	3/12	.	.	.	T/17	.	.	.	.
T/67	.	.	1/12	.	T/75	.	.	.	.	.	.
.	.	T/25	.	.	.	.	T/50	.	.	T/100	T/50
T/33	T/33	.	T/41	.	.	T/44	T/100	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	T/6	.	.	T/11	.	.	.	.	.
.	.	.	3/29	.	.	.	T/67	.	.	.	.
.	.	.	T/12	.	.	.	.	.	.	.	.
T/33	.	.	T/6	.	.	.	T/33	.	.	.	.
.	T/100	.	T/53	.	.	.	T/67	.	.	.	.
1/33	.	.	T/18	.	T/25	T/11	T/33	.	.	.	.
T/67	T/33	.	T/47	.	T/25	T/67	T/100	.	.	.	.
.	T/33	T/25	1/100	.	1/100	T/22	T/67	.	.	.	.
T/33	.	.	1/18	T/100	.	.	.	.	.	.	.
.	T/67	.	1/12	.	T/25	T/11	.	.	.	.	.
T/33	T/33	T/75	T/6	.	.	T/33	T/17	T/50	T/57	T/25	.
.	.	.	1/59	.	.	.	.	.	.	.	.

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Alexander, Billy G., Jr., Frank Ronco, Jr., E. Lee Fitzhugh, and John A. Ludwig. 1984. A classification of forest habitat types of the Lincoln National Forest, New Mexico. USDA Forest Service General Technical Report RM-104. 29 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

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Keywords: Forest vegetation, New Mexico, habitat types, plant communities, plant associations, forest ecology, and forest management.

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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